NORMANDEAU ASSOCIATES

Biota Monitoring Study (Year 5)

Kin-Buc Landfill

Operable Unit 2

1999

Prepared for:

KIN-BUC, INC.
and
SCA SERVICES, INC.

Edison Township, Middlesex County,
New Jersey

Prepared by:

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Normandeau Project No. 16148.005

June 2000

567881

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EMCON/OWT, Inc.
A Shaw Group Company

1 International Boulevard, Suite 700, Mahwah, NJ 07495 — Tel No. (201) 512-5700 Fax No. (201) 512-5786

TRANSMITTAL

Project/Task No.: 791186

TO: Ms. Grisell V. Diaz-Cotto
New Jersey Remediation Branch
US Environmental Protection Agency
290 Broadway - 19th Floor
New York, NY 10007-1860

DATE: May 24, 2002

RE: First Quarter 2002 Monitoring Report
OU1/OU2, Kin-Buc Landfill Superfund Site

WE ARE SENDING:

QUANTITY	DESCRIPTION
1	Monitoring Report
1	WMI cover letter

For Your:		Sent By:	
x	USE		REGULAR MAIL
	APPROVAL		FEDERAL EXPRESS
	REVIEW/COMMENTS	X	UPS
x	INFORMATION		COURIER
	OTHER		AIRBORNE

COMMENTS: Grisell: Please find enclosed one copy of the First Quater 2002 Monitoring Report prepared for the Kin-Buc Landfill.

cc: Michael Schumaci

BY: Licardi

-n:\proj\kinbuc\791186\transmittal\gris-trn.doc-95\pc:1 Print 3 copies: ORIGINAL - Recipient COPY - EMCON File COPY - Originator

WASTE MANAGEMENT

VIA FED EX AND US MAIL

May 21, 2002

Ms. Grisell V. Diaz-Cotto
New Jersey Remediation Branch
U.S. Environmental Protection Agency
290 Broadway, 19th Floor
New York, NY 10007-1860

RE: First Quarter 2002 Monitoring Report
Operable Units 1 and 2
Kin-Buc Landfill Superfund Site

Dear Ms. Diaz-Cotto:

Attached please find two copies of the First Quarter 2002 Monitoring Report for Operable Units 1 and 2 of the Kin-Buc Landfill Superfund Site. The report was prepared on behalf of the Respondents by EMCON/OWT ENVIROTECH of Mahwah, New Jersey. Mr.Adam Licardi is EMCON/OWT's project manager for this work.

Please call me if you have any questions at (732) 985-4757.

Sincerely,

Representing SCA Services, Inc., and Kin-Buc, Inc.,

Carl Januszkiewicz
Alternate Facility Coordinator

cc: Ian R. Curtis - NJDEP
Richard Hoyt - US Filter
Steve Joyce - SCA
Michael Schumaci - EMCON/OWT
Kris Hallinger - BB & L

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1.0 EXECUTIVE SUMMARY

Kin-Buc Landfill (Operative Unit 2) in Edison, New Jersey is a decommissioned facility subject to a US EPA "Record of Decision" which specifies that certain sediments in Edmonds Creek Marsh containing PCB concentrations greater than 5 parts per million (ppm) be removed. Edmonds Creek and Edmonds Creek Marsh are part of a 56-acre estuarine intertidal emergent wetland, adjacent to Kin-Buc, which flows into the Raritan River. The water is brackish. The affected sediments are mostly a mixture of silts and clays classified as sulfaquents and sulfihemists by the U.S. Geological Survey.

Prior to removal PCB concentrations in Edmonds Creek sediments adjacent to Kin-Buc were as high as 300 ppm immediately downstream from the discharge channel of a storage lagoon known then as "Pool C" (see Figure 4-1 at the end of Section 3.0). Throughout a section of Edmonds Creek, beginning approximately 1,500 feet upstream from the "Pool C" discharge and ending at the confluence of Edmonds Creek with the Raritan River 2,000 feet downstream, sediment PCB concentrations exceeded 5 ppm at eleven of forty individual sample locations within the stream channel. The average concentration for these eleven was 56.7 ppm. The mean for all forty was 17.0 ppm. Areas where sediment concentrations were high (> 5.0 ppm) did not include the entire width of the stream channel. In each case where high concentrations were found, they were restricted to either the center of the channel or to one of the stream banks. Thus, the contamination discovered in Edmonds Creek was not evenly distributed.

At present, remediation has been completed through selective removal of sediment from five areas (referred to as Remediated Zones 1 through 5) where PCB concentrations exceeded 5 ppm. In addition, the landfill has been capped and a slurry wall constructed around the perimeter. A leachate collection system and a leachate treatment plant have been constructed and are in operation. In the marsh wetlands restoration and maintenance has been undertaken with considerable success.

The performance objectives of the five year monitoring program are to: 1) evaluate whether the remediation effort was successful; 2) identify reductions in biological uptake of residua PCBs in targeted species that have recolonized the remediated areas; 3) document the re-establishment of invertebrate and fish communities in the remediated areas; and 4) identify decreasing PCB trends over time in the sediment and tissue concentrations; and improved biotic integrity in the ecological data. Attainment of these objectives would greatly reduce the ecological threats associated with the contaminated sediment while preserving a significant portion of the existing wetland ecosystem by avoiding extensive excavation. All collections and analyses were made according to a US EPA approved "Biota Monitoring Plan" prepared by EMCON, Mawah, New Jersey, during the fifth and final year of a planned five year monitoring program.

In order to assess compliance with the above stated performance objectives seven sampling zones were established in Edmonds Creek at the beginning of this study to collect and analyze sediment, fiddler crab, and benthic macroinvertebrate samples. As noted, five of the Edmonds Creek zones were established within remediated areas where sediment concentrations exceeding 5 ppm were removed. Two zones were established in unremediated areas of Edmonds Creek where sediment concentrations were less than 5 ppm. Unremediated zones were not excavated. Two additional zones were established in a reference creek with similar water quality and sediment characteristics to Edmonds Creek but subject to a different drainage system. Reference zones were sampled in the same manner as Edmonds Creek zones. Fish and mummichog tissue samples were collected and analyzed from eight zones in both the Edmonds Creek (five from remediated and three from unremediated areas) and Reference Creek systems. In Edmonds Creek seven of the eight zones from where mummichog tissues were collected corresponded to zones where sediment, fiddler crabs, and invertebrate samples were collected. The eighth zone (Unremediated Zone 3) was established in a tributary to Edmonds Creek that flows adjacent to Kin-Buc.

Sediment samples were analyzed for PCBs, Total Organic Carbon (TOC), and grain size distribution. A bioaccumulation study was conducted by exposing *Macoma nasuta* to sediments collected from the seven Edmonds Creek and two Reference Creek zones for 28 days. Macoma tissues were analyzed for PCBs and lipids as were fiddler crab and mummichog tissues. All fish captured in addition to mummichogs were identified and counted. Benthic macroinvertebrate data were reduced to a set of ecological metrics including taxonomic richness and community density, percent contribution of the dominant taxon, diversity, and evenness.

During August and September 1999 staff biologists from Normandeau Associates, Spring City, Pennsylvania visited Edmonds Creek to collect the sediment, fiddler crab, and mummichog tissue samples, along with fish and benthic macroinvertebrates. Results of the analyses are summarized as follows:

Sediment

In 1999 whole sediment PCB analysis (dry weight) resulted in mean values that ranged from 1.2 to 16.5 ppm within individual Edmonds Creek (both remediated and unremediated) zones, and were 0.6 and 0.4 ppm within the Reference Creek zones. The highest means of 6.6 and 16.5 ppm were found in the two unremediated zones. Aroclors 1248, 1254, and 1260 were detected.

Prior to removal of contaminated sediments mean PCB concentrations in the remediated zones ranged from 2.0 to 45.3 ppm. In 1995 remediated zone means ranged from 0.3 to 0.4 ppm and indicated a mass reduction between 1.7 and 44.8 ppm in individual zones. In 1999 remediated zone means ranged from 1.2 to 6.4 ppm. Mass PCB reductions in individual remediated zones presently ranges between 0.1 and 45.3 ppm. During 1995 to 1999 mean PCB concentrations in Edmonds Creek remained below the remediation standard within four of five remediated zones and ranged from 0.3 to 6.4 ppm.

The areas where sediment concentrations were high (> 5.0 ppm) did not include the entire width of the stream channel. Thus, the residual contamination remaining in Edmonds Creek is distributed in a similar uneven pattern as that shown by the pre-remediation data, but at lower concentrations. Particularly encouraging results were obtained from Remediated Zone 3, immediately downstream from the old "Pool C" location, where mean concentrations were 3.0 ppm or less each year.

The cumulative mean for forty samples collected from the seven zones in Edmonds Creek prior to the remedial excavation (completed in July 1995) was 17.0 ppm. During 1995 a mean of 0.6 ppm was calculated from all twenty-eight post-remediation samples in Edmonds Creek indicating that, on a broad scale, the effort reduced the contaminant levels by 16.4 ppm. In 1996 the cumulative mean at Edmonds Creek increased to 2.9 ppm. In 1997 and 1998 the cumulative mean was 3.9 ppm, and in 1999 it was 5.3 ppm. Thus, at present, the mass reduction over the length of the study area is on average 11.7 ppm. The cumulative mean of 5.3 ppm, observed in 1999, was disproportionately influenced by an atypically high value from Unremediated Zone 2. Exclusive of this value, the cumulative mean for the remaining twenty-seven samples would have been 3.9 ppm. From 1995 to 1999 cumulative means within the remediated zones were 0.4, 2.1, 1.8, 2.2, and 2.8 ppm, respectively.

Fiddler crabs

In 1999 mean total PCB tissue concentrations (wet weight) in the fiddler crab samples ranged from 0.6 to 1.8 ppm within individual Edmonds Creek zones, and were 0.1 ppm within both Reference Creek zones. Aroclors 1248, 1254, and 1260 were detected. During 1995 to 1999 mean PCB concentrations within individual Edmonds Creek zones ranged from 0.5 to 3.8 ppm.

Prior to the remedial excavation (1990), US EPA obtained results as high as 14.0 ppm from three tissue samples collected in Edmonds Creek. During 1995 to 1999 cumulative means of 1.4, 1.8, 1.6, 1.3, and 1.2 ppm were calculated from Edmonds Creek, respectively, indicating a slight decrease in body burdens throughout the study period. During 1995 to 1999 cumulative means within individual remediated zones were 1.0, 1.7, 1.6, 1.1, and 1.1 ppm, respectively.

Macoma clams

In 1999 mean total PCB tissue burdens accumulated (wet weight) in the macoma clam samples ranged from 0.1 to 2.0 ppm within individual Edmonds Creek zones, and were less than 0.1 ppm within both Reference Creek zones. Aroclors 1242, 1248, 1254, and 1260 were detected. During 1995 to 1999 mean PCB accumulations within individual Edmonds Creek zones ranged from 0.1 to 2.7 ppm.

During 1995 to 1999 cumulative means of 0.8, 1.4, 0.9, 0.5, and 0.7 ppm were calculated from Edmonds Creek, respectively, indicating a slight decrease in body burden throughout the study period. The 1995 to 1999 cumulative means from the remediated zones were 0.5, 1.1, 0.5, 0.3, and 0.3 ppm, respectively.

Mummichog

In 1999 mean total PCB tissue concentration (wet weight) in the mummichog samples ranged from 1.2 to 2.7 ppm within individual Edmonds Creek zones, and ranged from 0.2 to 0.4 ppm within individual Reference Creek zones. Aroclors 1248, 1254, and 1260 were detected. During 1995 to 1999 mean concentrations within individual Edmonds Creek zones ranged from 0.5 to 2.8 ppm.

During 1995 to 1999 cumulative means of 0.7, 1.1, 1.9, 1.0, and 1.9 ppm were calculated from Edmonds Creek, respectively. Thus, PCB body burdens fluctuated between 1 and 2 ppm during the course of the study period.

Benthic macroinvertebrates and fish communities

During 1995 to 1998 the benthic macroinvertebrate data from Edmonds Creek indicated a shift in dominance from a community represented mostly by the tubeworm *Limnodrilus hoffmeisteri* at the upstream zones to one with taxa more commonly associated with brackish water downstream. This shift corresponded to a shift in the tidal characteristics of Edmonds Creek. In 1999 *Limnodrilus* were only common at the most upstream zone. The data indicated that a record drought in 1999 reduced flow in Edmonds Creek; resulting in a more saline environment than had been observed during prior years. Two taxa, *Neanthes succinea* and *Cyathura polita* that prefer more saline conditions, were dominant at all Edmonds Creek zones.

In 1999 the fisheries data from Edmonds Creek differed from data collected at Reference Creek. A total of 1,527 fish representing 6 species was identified from Edmonds Creek compared to 749 fish and 8 species from Reference Creek. Mummichogs and Atlantic silversides ranked first and second in abundance at Edmonds Creek. Atlantic menhaden and Atlantic silversides were most common at Reference Creek. During 1995 to 1999 the total number of fish captured from Edmonds Creek ranged from 970 to 1,837 and the total number of species ranged from 4 to 15. During 1995 to 1999 the total number of fish identified from Reference Creek ranged from 697 to 1,533 and the total number of species identified ranged from 6 to 12. Following five years of collection, a total of 21 species have been captured from Edmonds Creek compared to a total of 16 from Reference Creek. Fish appeared to have completely recolonized Edmonds Creek by 1996 or 1997, when the greatest numbers of species were captured.

During 1995 to 1998 invertebrate community metric calculations from Edmonds Creek indicated a gradual increase in biotic integrity at zones upstream from and adjacent to Kin-Buc. The upstream improvement in biotic integrity was illustrated by increases in community richness, diversity, and a corresponding decrease in the percent composition of the dominant taxa. Downstream from Kin-Buc metric results tended to fluctuate from year to year and did not reveal any clear trends. In 1999 community metrics were influenced by drought conditions and a corresponding increase in salinity. Richness, density, and diversity all decreased and the percent contribution of the dominant taxon increased. Declines in richness and density were also observed from the Reference Creek data. It was apparent that the invertebrate communities in both creeks were being influenced primarily by climatic changes. Recolonization of the Edmonds Creek sediments following the remediation effort therefore appeared to be complete.

2.0 INTRODUCTION AND BACKGROUND

During August and September 1999, a series of sediment, fiddler crab, fish, and benthic macroinvertebrate samples were collected from Edmonds Creek on behalf of Kin-Buc, Inc. and Waste Management at Kin-Buc Landfill, Edison, New Jersey. Collections were made during the final year of a five year biota monitoring study. Kin-Buc is a decommissioned landfill located adjacent to and immediately south of the Edmonds Creek Marsh (see enclosed Drawings 1, 1.5, 2, and 2.5). While operative, discharges from the landfill resulted in contamination of marsh sediments with polychlorinated biphenyls (PCBs) and, to a lesser extent, polynuclear aromatic hydrocarbons (PAHs) and inorganics. The landfill became subject to a Remedial Investigation/Feasibility Study (RIFS), with an area called Operable Unit 2 focused on the marsh. Remedial Investigation data verified the presence of PCBs in both the marsh sediments and associated aquatic biota. Pre-remediation sediment PCB concentrations measured within the Edmonds Creek channel and banks were as high as 300 parts per million (ppm) (Wehran 1992). Throughout the marsh, PCB concentrations averaged less than 10 ppm (US EPA 1993). Further, pre-remediation data showed that PCB concentrations in the Edmonds Creek Marsh were higher than those in a second nearby marsh, established as a reference area and not subject to discharges from Kin-Buc.

A United States Environmental Protection Agency Record of Decision (US EPA 1992a) specified that sediments in the Edmonds Creek Marsh containing PCB concentrations greater than 5 ppm be removed. Sediment removal has been completed through selected excavation of five areas, referred to as Remediated Zones 1 through 5. This remedy was based on sediment concentrations, and there was no biological performance standard per se in the Record of Decision (EMCON 1995). The removal of the most heavily contaminated sediment from the remediated zones was expected to reduce the levels of PCBs in the tissues of the aquatic organisms living there. Two additional zones referred to as Unremediated Zones 1 and 2 were also established as part of this study effort. These zones were not excavated because sediment concentrations there were less than 5 ppm. They were included to provide additional data to evaluate the status of the Edmonds Creek study area.

Edmonds Creek and the Edmonds Creek Marsh Area are part of a 56-acre tidal wetlands that drains into the Raritan River in Middlesex County (Edison Township) at Edison, New Jersey (Drawings 1 and 2). Photographs 1 through 8 showing the Edmonds Creek study area are presented as Figure 1. The Edmonds Creek Marsh Area is part of a much larger tidal wetlands complex of 437 acres. The entire system is classified by the National Wetlands Inventory Program as an Estuarine Intertidal Emergent Wetlands (E2EM) (EMCON 1995). Land use within the drainage basin is primarily industrial and includes Edison Landfill, adjacent to Kin-Buc; ILR Landfill, nearby; Edgeboro Landfill, in East Brunswick; and East Brunswick Landfill (decommissioned), opposite Kin-Buc. Phragmites (*Phragmites australis*) is the predominant form of vegetation present, growing from acidic mucky soils classified by the United States Geological Survey as sulfaquents and sulfihemists (EMCON 1995). The water is brackish with salinity ranging between 0.5 and 15 parts per thousand (ppt).

The Reference Area is also a brackish water tidal marsh. It is located directly across the Raritan River from the Edmonds Creek Marsh Area (Drawings 1.5 and 2.5). It was used as a reference area during previous studies concerning Kin-Buc, including the RIFS, and has continued to serve as a reference area for this monitoring effort. The reference area is in a different watershed from Edmonds Creek and thus is part of a separate drainage system. A small unnamed stream flows through the marsh and was referred to as Reference Creek for this study. Vegetation, sediment, and water quality characteristics are similar to those found in Edmonds Creek.

Information contained here-in was gathered as part of a biota monitoring program that was conducted for a five year period. After five years the monitoring program will be reviewed and the necessity for continuing biological monitoring will be determined. This report provides several recommendations for scope reductions pertaining to future study.

This report summarizes data collected in accordance with a US EPA approved monitoring plan prepared by EMCON in June 1995. The plan, entitled "Biota Monitoring Plan, Kin-Buc Landfill, Operable Unit 2", states three study objectives, as follows:

1) An analysis of PCBs in sediments collected from remediated and unremediated zones in Edmonds Creek and from Reference Creek. These data will be used to ascertain whether the clean-up effort was successful in achieving the 5 ppm criterion for the remediated areas. Residual PCB concentrations will provide information concerning the potential for future biological uptake from the sediments.

2) An assessment of the degree of biological uptake of residual PCBs in targeted species that recolonize the remediated areas. This was accomplished by analyzing tissue samples from two species collected from the study streams and from a laboratory bioaccumulation study with a third species. Target species collected in the field were the brackish water fiddler crab (*Uca minax*), a burrower, and a killifish (*Fundulus heteroclitus*), commonly known as the mummichog, which lives in the water column. By analyzing tissue from these two target species, it will be possible to ascertain a degree of differential uptake of the contaminant by organisms with different life histories and habitat requirements. A second burrower, a clam commonly known as the bent-nose macoma (*Macoma nasuta*), was introduced to sediments collected from the study area under controlled laboratory conditions. After a 28-day exposure period, tissue samples from these were analyzed for PCBs and the data compared to data produced from the analysis of fiddler crab tissue.

3) A qualitative fish survey and a quantitative benthic community survey conducted to monitor the re-establishment of these communities in the remediated areas.

These analyses were repeated each year to detect changes in the body burdens of the target species over an extended period. Ideally, successful removal of PCBs from the Edmonds Creek Marsh produced a reduction in contaminant concentrations over the course of time. Trend analyses of five years of data are presented in this report.

During 1999 all samples of sediment, fiddler crab and mummichog tissue, and fish and benthic invertebrates were collected by Normandeau Associates. The 28-day bioaccumulation analysis using macoma clams was conducted by EnviroSystems, Inc., Hampton, New Hampshire. Chemical analyses of the sediment and tissue samples were performed by Lancaster Laboratories, Inc., Lancaster, Pennsylvania. Grain size analyses of the sediments were completed by Valley Forge Laboratories, Inc., Devon, Pennsylvania. Fish and benthic macroinvertebrate samples were analyzed by Normandeau. This project is coordinated and this report was prepared by Normandeau Associates at Spring City, Pennsylvania.

FIGURE 1. EDMONDS CREEK MARSH AREA (JULY, 1996)

1. Edmonds Creek Marsh Area: upstream view from Operable Unit 2.

2. Edmonds Creek Marsh Area: downstream view from Operable Unit 2.

FIGURE 1. (CONTINUED)

3. Edmonds Creek: Remediated Zone 2 at low tide.

4. Edmonds Creek: Remediated Zone 2 at low tide.

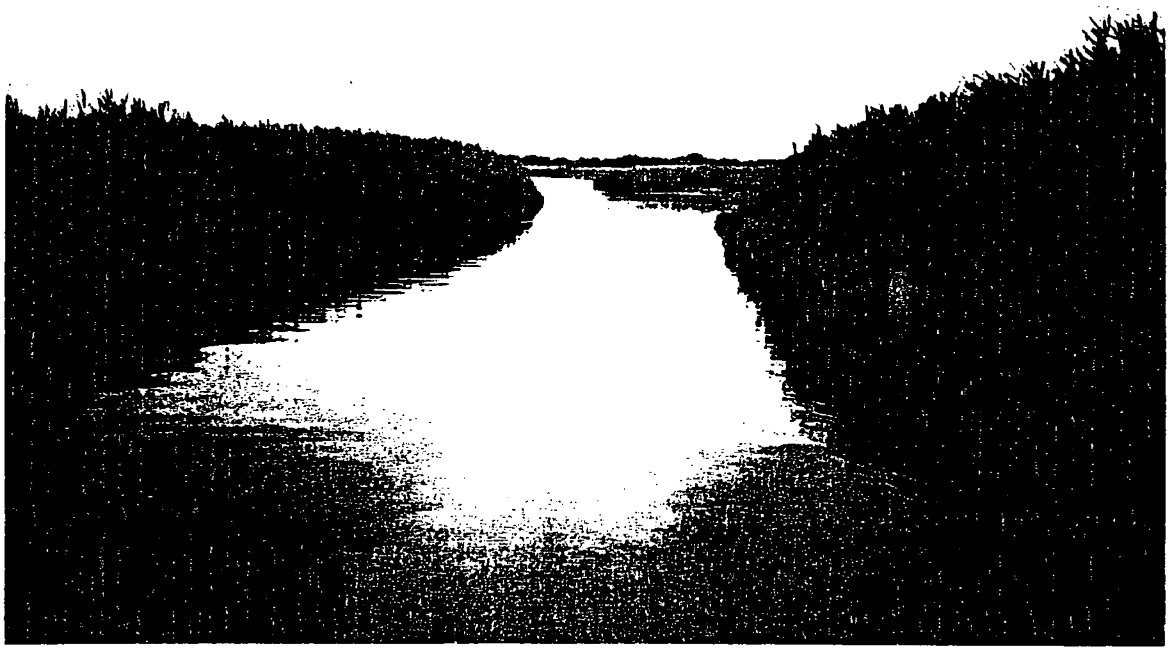
FIGURE 1. (CONTINUED)

5. Edmonds Creek: Remediated Zone 2 at high tide.

6. Edmonds Creek: Remediated Zone 4 at mid tide.

FIGURE 1. (CONTINUED)

7. Edmonds Creek: Fiddler crabs and sample location marker UN-CBEN-01AR at Unremediated Zone 1.



8. Edmonds Creek: Unremediated Zone 1 near confluence with the Raritan River.

3.0 SEDIMENT ANALYSIS

Polychlorinated biphenyls are synthetic organic compounds that had been in commercial use since 1929. They were manufactured by the Monsanto Chemical Company under the trade name "Aroclor" by the chlorination of the biphenyl molecule (US FWS 1984). This reaction yielded a wide range of compounds differing in the number and position of chlorine substitutions on the biphenyl molecule. PCBs are very stable and are resistant to most chemical reactions. They are no longer manufactured in the United States. The physical properties of PCBs depend upon the percentage of chlorine on the biphenyl molecule. PCBs with a low percentage of chlorine (Aroclor 1060, 1221, 1232, 1242, and 1248) are mobile, colorless oils. Those with an intermediate percentage (Aroclor 1254, 1260, and 1262) are viscous liquids or sticky resins. Higher percentages of chlorine (Aroclor 1268 and 1270) result in white powders (US EPA 1984). PCBs have low solubility in water, but are soluble in organic solvents and, importantly, lipids (fatty tissue). They have entered the aquatic environment through waste discharges to storm and sanitary sewers, dumping of PCB-contaminated materials into landfills and scrapyards, and spills associated with production and use. PCBs are listed by the US EPA as a priority pollutant.

PCBs adsorb (attach) onto stream sediments and waterborne organic particulate matter. This characteristic of PCBs causes stream sediments to act as a repository for them in the environment. Sediment concentrations are usually higher than the surrounding water. Invertebrates and fish bioaccumulate PCBs in tissue at concentrations higher than the concentration found in ambient water. Species at higher trophic levels are subject to higher residual concentrations. Biological contamination may occur through a variety of routes. Aquatic organisms may incorporate PCBs from water, sediment, or food items. For the most part, the lesser chlorinated congeners (chemically related compounds) are more readily subject to metabolism. The forms with five, six, and seven chlorine substitutions are resistant to chemical or biological degradation (US EPA 1990). PCBs are nearly immobile in aquatic environments when concentrations in the liquid phase are controlled by solubility, and transport is controlled by partitioning between stream sediments and water (US EPA 1990). However, low solubility compounds such as PCBs can be physically transported as a sorbent, on colloidal (suspended) clays and organic carbons, and as a solute within mobile organic substances such as oils. Tidal currents are a plausible mechanism for the distribution of PCBs throughout the Edmonds Creek Marsh Area.

Importantly from an ecological perspective not all congeners have the same effects. Discrimination of congeners appears operative at many physical, chemical, and biological levels: persistence in the environment varies; and bioaccumulation potential varies among congeners and across trophic (feeding) levels.

3.1 Materials and Methods

Collection

Nine composite sediment samples, analyzed for polychlorinated biphenyls, total organic carbon, and grain size distribution, were collected on 2 through 4 August 1999 at transect locations established for the 28-day bioaccumulation tests. Twenty-seven additional composite samples were collected over the same period at point locations established for collection of the fiddler crab tissue samples. Where transects were used as sampling locators, samples were taken from two transects within each of nine zones and composited to produce a discrete sample. These samples were homogenized in the field, a subportion removed for PCB, TOC, and grain size analysis, and the remainder (sufficient to fill a lined 10-gallon cooler) submitted for the 28-day bioaccumulation analysis. Sediment samples collected at the locations established for the crab tissue samples consisted of a composite of a minimum of five grabs each. A total of thirty-six individual samples (plus two field duplicates) was analyzed: twenty from five sampling zones at remediated areas within the Edmonds Creek channel; eight from two zones representing unremediated areas; and eight from two zones in the reference creek. Specific locations for each transect pair or sample point are shown on Drawings 1 and 1.5 and Figure 3. Sampling transects and points were established in the field by a surveyor and marked by driving labeled PVC pipes into the substrate. All samples were collected using a decontaminated shovel and/or Petite Ponar Grab sampler (Figure 2). Multiple grabs were composited at each sampling location, mixed until homogenous, transferred into glass containers, and chilled prior to transport to the analytical laboratory. Samples were taken from a depth of no more than six inches to represent substrate depths where exposure to feeding biota was likely. Sediment collection and handling procedures were selected to conform to protocols established by the American Society for Testing and Materials (ASTM 1990).

<u>Analysis</u>

PCB analyses were conducted according to US EPA Method 8082 (US EPA 1992). Organic carbon was analyzed according to US EPA Method 415.1 and grain size analyzed according to the ASTM Method D-422 (ASTM 1994). Results of the PCB analyses were normalized according to the total organic carbon (OC) content of each sample using the equation:

$$\text{PCB concentration } (\mu g/g \text{ OC}) = \frac{\text{PCB concentration } (\mu g/kg)}{\% \text{ organic carbon} \times 10}$$

and reported both as micrograms/kilogram dry weight (parts per billion) and micrograms/gram organic carbon (parts per million). This normalization standardizes the PCB concentrations to the organic carbon content of each sample and allows for an additional comparison of the results. However, because the remediation standard is based upon the whole sediment concentrations, it is these results that will be emphasized in the sections that follow. The data are described according to their range, mean, standard error of the mean, and coefficient of variation (Remington and Schork 1985).

3.2 Results and Discussion

The PCB results from the seven zones in Edmonds Creek are presented first, followed by results from the two reference zones (Table 1). Quality control results, and Analysis Reports submitted by Lancaster Labs (PCB and OC) and Valley Forge Labs (grain size) are provided as Appendix A. Results are shown for seven Aroclors and for Total PCBs, expressed as whole sediment concentrations in micrograms per kilogram dry weight (μg/kg dry wt). Additional results reported are the percentages of organic carbon (OC) (Table 1) and the percentages of silt and clay (Tables 1 and 2) in the samples. Results for transect and sampling point locations are presented in upstream to downstream order beginning with Remediated Zone 1 and progressing downstream to Unremediated Zone 1 (see Drawings 1 and 1.5 and Figure 2) (e.g., sample A10+50L was collected from Remediated Zone 1, A21+00 from Remediated Zone 2, etc.). Samples collected from reference zones are reported in an upstream direction (e.g., RA-ABIO-01/01A was taken from Reference Zone 1).

3.2.1 Edmonds Creek Zones

The 1999 results for Aroclors 1016, 1221, 1232, and 1242 were below the minimum detection limit of the analytical method (Table 1). Low values were estimated by assuming a value of one-half the detection limit and were U-qualified on the Laboratory Analysis Reports. Low values, between the minimum detection limit and the limit of quantification, were J-qualified. Aroclors 1248, 1254, and 1260 were found at detectable concentrations, ranging widely from 99 to 29,200 μg/kg dry wt in individual samples. Aroclors 1248 and 1254 were found in the greatest quantity.

Total PCB concentrations for individual samples (Sum of Aroclors) were also variable ranging from 734 to 43,675 μg/kg dry wt (0.734 and 43.675 ppm, respectively). Twenty of twenty-eight sample locations yielded results below the 5 ppm remediation standard. Exceptions were observed from three locations in Unremediated Zone 2, two locations in Remediated Zone 4, and three locations in Unremediated Zone 1. High values of 43,675 (Station UN-ABEN-02AL) and 15,355 (Station UN-ABIO-02/02A) μg/kg dry wt (43.675 and 15.355 ppm) were observed at Unremediated Zone 2. A high value of 11,406 μg/kg dry wt (11.406 ppm) was observed at Station A42+25/46+50 (average of an original sample and a field duplicate) in Remediated Zone 4. High PCB concentrations were not measured at either station until 1999. These results suggest that redistribution of residual PCBs has occurred following the remediation effort. A high value of 9,268 μg/kg dry wt (9.268 ppm) was also observed at Station UN-ABIO-01AL in Unremediated Zone 2. Although higher than the remediation standard, this value was considerably less than values of 48,535 and 33.338 μg/kg dry wt (48.535 and 33.338 ppm) observed at this station during 1997 and 1998, respectively. The results from Station UN-ABIO-01AL suggest that PCB contamination may ultimately dissipate from areas where high concentrations have formed.

Within particular zones, mean PCB concentrations ranged between 1,214 (Remediated Zone 2) and 16,535 (Unremediated Zone 2) μg/kg dry wt, with the lowest concentrations occurring at the most upstream remediated zones. Mean PCB concentrations (by zone) were between 1 and 2 ppm at Remediated Zones 1, 2 and 5; near 3 ppm at Remediated Zone 3; near 6 ppm at Remediated Zone 4 and Unremediated Zone 1; and near 16 ppm at Unremediated Zone 2. The results did not display any clear spatial pattern relative to the proximity of the sample zones to OU2.

The concentrations of total organic carbon in individual samples ranged from 0.3 to 2.7 percent. Following normalization for organic carbon, total PCB concentrations for individual samples ranged widely from 33.8 to 7,279.2 micrograms per gram organic carbon (ppm) (Table 1). Mean PCB concentrations (by zone) were: 125.3, 88.2, and 237.1 ppm at Remediated Zones 1, 2, and 5, respectively; 520.6 ppm at Remediated Zone 3; 602.6 and 798.2 ppm at Remediated Zone 4 and Unremediated Zone 1; and 2,516.6 ppm at Unremediated Zone 2. Thus, zones that displayed the highest whole sediment concentrations on a dry weight basis also had the highest organic carbon normalized concentrations (in order of rank they were the same).

The silt/clay percentages in individual samples ranged from 47.4 to 97.3 percent (Tables 1 and 2). Most of the samples consisted of a silt/clay matrix with sand the third most predominant particle size. Most of the samples consisted of well over 80 percent silt and clay fines, and a large component of coarse particulate organic matter (detritus). Sand was a major constituent of the substrate only at Station UN-ABIO-02/02A in Unremediated Zone 2 where the percent by weight was 52.4 percent. The high percentages of silt/clay fines show that the Edmonds Creek sediments have a high capacity to sorb residual PCBs, particularly where high concentrations of organic carbon are also present.

3.2.2 Reference Creek Zones

Sediment concentrations for specific Aroclors measured from the Reference Area, on the opposite side of the Raritan River, were consistently lower than those from Edmonds Creek. Aroclors 1248, 1254, and 1260 were detected from all eight reference samples. Concentrations for these three Aroclors in particular samples ranged between 29J and 295 µg/kg dry wt. Aroclors 1248 and 1254 were the most concentrated PCBs found in the reference samples.

Total PCB concentrations in individual samples were fairly consistent, relative to concentrations from the Edmonds Creek samples, and ranged from 197 to 834 µg/kg dry wt (0.197 and 0.834 ppm). By zone, sample means were 622 (Zone 1) and 380 (Zone 2) µg/kg dry wt; less than 1 ppm in each case.

Total organic carbon in individual samples ranged between 0.3 and 1.5 (an average of two duplicate samples) percent. Upon normalization for OC content, individual PCB values ranged between 30.3 and 91.7 µg/g OC. Mean values by zone were 64.2 (Zone 1) and 50.7 (Zone 2) µg/g OC.

The silt/clay percentage in individual samples ranged from 93.3 to 97.4 percent. Coarse particulate organic matter was also prevalent.

3.2.3 Five Year Trend

<u>Edmonds Creek Zones</u>

Temporal trends for total PCB concentrations in sediment at each zone are displayed as Figures 4 through 10. Because the remediation standard of 5 ppm is based upon whole (unnormalized) sediment concentrations, these results are emphasized for the trend analysis. All results will be given as parts per million.

To date, a five-year pattern of increasing PCB concentrations has developed at Unremediated Zone 2, and Remediated Zone 4. PCB concentrations have essentially remained stable from 1996 through 1999 at Remediated Zones 1, 2, and 3. Decreasing concentrations have been observed from 1996 to 1999 at Remediated Zone 5. PCB concentrations at Unremediated Zone 1 rose from 1995 to 1997 and decreased thereafter.

During 1995, immediately following the remediation effort, mean sediment concentrations were relatively low (from less than 1 to slightly over 1 ppm) within each zone. In some cases sediment means were very near the means calculated from the reference zones. These results indicated that the remediation effort successfully removed most of the contaminant, reducing concentrations well below the remediation standard. One year later, during 1996, mean PCB concentrations had increased by 1 to 5 ppm at all but one of the zones. Within particular zones, 1996 means ranged from less than 1 to slightly over 5 ppm. During 1997 and 1998 means tended to remain near 1996 values and remained below the remediation standard at all zones except Unremediated zone 1. In 1999 increasing PCB concentrations produced means that exceeded the remediation standard within Remediated Zone 4 and Unremediated Zone 2. Currently, the remaining four remediated zones show PCB means below 5 ppm.

It appears that residual PCB's present throughout the Edmonds Creek Marsh Area tend to be transported towards the creek channel following periods of rainfall and then form localized concentrations, due in part to tidal redistribution.

Remediated Zones 1 and 2

The mean PCB concentration at Remediated Zone 1 was 0.422 (J) ppm in 1995. From 1996 to 1999 means stabilized within a range of 1 to 2 ppm (Figure 4). These values were 0.786 (1996), 1.038 (J) (1997), 0.947 (1998), and 1.649 (1999) ppm.

At Remediated Zone 2 a nearly identical trend was observed. A 1995 mean of 0.331 (J) ppm was followed by means of 1.374 (1996), 0.963 (J) (1997), 1.145 (1998), and 1.214 (1999) ppm (Figure 5). Residual contamination at both zones has remained well below the remediation standard. Evidently, tidal inundation in combination with surface runoff following rain events has redistributed residual PCBs, and concentrations at these upstream zones will remain near 1 or 2 ppm.

Unremediated Zone 2 and Remediated Zone 3

At Unremediated Zone 2 a mean PCB concentration of 0.963 ppm was measured immediately following the remediation effort (Figure 6). Subsequent means were 1.577 (1996), 2.366 (1997), 2.327 (1998), and 16.535 (1999) ppm. Evidently, tidal redistribution of residual PCBs formed a localized concentration at Station UN-ABEN-02AL between 1998 and 1999.

A dissimilar trend was observed a short distance downstream from OU2 at Remediated Zone 3. There, a post-remediation mean of 0.528 ppm (1995) was followed by means of 1.674 (1996), 2.340 (1997), 1.970 (1998), and 3.206 (1999) ppm (Figure 7). PCB concentrations within Zone 3 remain approximately 2 ppm below the remediation standard. Zone 3 was located near a former storage lagoon and discharge known as "Pool C" where contamination was as high as 300 ppm.

Remediated Zones 4 and 5

At Remediated Zone 4, further downstream from OU2, a post remediation mean of 0.403 ppm was followed by means of 5.558 (1996), 2.698 (1997), 4.234 (1998), and 6.410 (1999) ppm (Figure 8). Annual means fluctuated to a greater extent at Zone 4 than at any of the upstream zones, within a range of 2.5 to 6.5 ppm. Interestingly, relatively low means were recorded following excavation and construction of a slurry wall around an area known as the "Oil Seeps Area" during 1996. The "Oil Seeps Area" was a short distance upstream from Zone 4.

Conversely, a decreasing trend for PCB concentrations was observed near the mouth of Edmonds Creek at Remediated Zone 5. The 1995 through 1999 means were 0.299, 3.540, 1.966, 2.866, and 1.899 ppm, respectively (Figure 9). Concentrations have remained below the remediation standard each year.

Unremediated Zone 1

High PCB concentrations at Station UN-ABIO-01AL contributed to annual means that exceeded the remediation standard during 1997 to 1999 at Unremediated Zone 1. Unremediated Zone 1 is at the mouth of Edmonds Creek. Annual means there were 1.236 (1995), 5.211 (1996), 15.846 (1997), 13.818 (1998), and 6.558 (1999) ppm (Figure 10). Thus, during the past two years of monitoring, the contaminant at Station UN-ABIO-01AL appears to be dissipating.

Reference Creek Zones

Temporal trends for sediment PCB concentrations within Reference Creek zones are shown as Figures 11 and 12. Exclusive of three individual sample values from the 1996 collections, PCB concentrations within

Reference Creek were near or below 1 ppm during the course of the study period. High 1996 values of 8.535 (Station RA-ABEN-01L), 8.496 (Station RA-ABEN-02AL), and 5.659 (Station RA-ABIO-02/02A) dissipated the following year but indicated a contaminant source separate from Kin-Buc. Within Reference Zone 1 sample means were 0.310 (U) (1995), 2.794 (1996), 0.613 (J) (1997), 0.838 (1998), and 0.622 (1999) ppm. A nearly identical pattern was observed within Reference Zone 2 where annual means were 0.300 (U) (1995), 3.692 (1996), 0.526 (J) (1997), 0.450 (1998), and 0.380 (1999) ppm. Low concentrations of PCB's in Reference Creek confirm the ubiquitous nature of PCB contamination.

3.2.4 Comparisons with data from the Remedial Investigation/Feasibility Study

At the beginning of this monitoring effort US EPA assigned a criterion of five parts per million to be used as a conceptual framework from which the success of the remediation would be evaluated. The implicit objective of the remediation was to ultimately reduce potential exposure to humans and wildlife. Although complete success in achieving this standard cannot currently be documented from all of the zones, it does appear that most of the contaminant has been removed from the stream channel and, from a broader perspective, a considerable reduction in exposure potential has been achieved. Comparing the data collected from this effort with data collected immediately prior to the remedial excavation illustrates this point. These data are presented in the RIFS report pertaining to this project, entitled: "Kin-Buc Landfill, Operable Unit 2, Draft Final Feasibility Study Report" (Wehran 1992). In the RIFS sample locations and sediment data from the Edmonds Creek channel, and throughout Edmonds Creek Marsh, are displayed as Figure 4.1 at the end of this section.

To provide valid comparisons with data collected after the remediation by Normandeau Associates, pre-remediation data were selected from all sample points located within the confines of the Edmonds Creek Channel. In short, forty such sediment results are used here to calculate pre-remediation means from the five remediated and two unremediated zones. Note that specific sample locations from the RIFS differ from the Biota Monitoring Study locations but were from within or very near the same zones.

Comparisons between pre-remediation means (ppm dry weight) and, 1995 and 1999 post-remediation means are:

Zone	Pre-remediation mean	1995 mean	1999 mean
Remediated Zone 1	30.8 (max = 81.0, n = 3)	0.4 (max = 0.5, n = 4)	1.7 (max = 4.0, n = 4)
Remediated Zone 2	7.6 (max = 17.3, n = 9)	0.3 (max = 0.4, n = 4)	1.2 (max = 1.4, n = 4)
Unremediated Zone 2	1.1 (max = 2.5, n = 3)	1.0 (max = 1.9, n = 4)	16.5 (max = 43.7, n = 4)
Remediated Zone 3	45.3 (max = 300.0, n = 10)	0.5 (max = 0.7, n = 4)	3.0 (max = 4.8, n = 4)
Remediated Zone 4	8.1 (max = 29.7, n = 6)	0.4 (max = 0.5, n = 4)	6.4 (max = 11.4, n = 4)
Remediated Zone 5	2.0 (max = 5.3, n = 6)	0.3 (max = 0.4, n = 4)	1.9 (max = 2.5, n = 4)
Unremediated Zone 1	1.1 (max = 2.5, n = 3)	1.2 (max = 1.8, n = 4)	6.6 (max = 9.3, n = 4)

Eleven of the forty results from the RIFS were above five parts per million. The average concentration for these eleven was 56.7 ppm. The cumulative mean for all forty pre-remediation samples was 17.0 ppm. Areas where sediment concentrations were high (>5.0 ppm) did not include the entire width of the stream channel. In each case where high concentrations were found, they were restricted to either the center of the channel or to one of the stream banks. Thus, the contamination discovered in Edmonds Creek was not evenly distributed.

In contrast, none of the twenty-eight results from 1995 were above 5.0 ppm. The average concentration for these twenty-eight was 0.6 ppm. Eight of twenty-eight results from 1999 were above five parts per million, and averaged 13.2 ppm. The cumulative mean for all twenty-eight was 5.3 ppm. Note that the cumulative mean for twenty-seven samples, exclusive of the single value of 43.7 ppm in Unremediated Zone 2, would be 3.9 ppm. Particularly encouraging results were obtained from Remediated Zone 3, immediately downstream from the old "Pool C" location, where mean concentrations remained at 3.0 ppm or less.

These data indicate that the majority of the contaminant remains removed from the remediated zones. The 1995 means indicate mass contaminant reductions between 1.7 and 44.8 ppm from individual zones. The 1999 means show mass reductions between 0.1 and 45.3 ppm from individual zones. As previously stated, the high means in Remediated Zone 4 and the unremediated zones appear to be due to tidal redistribution (lateral transport and concentration) of residual PCBs. Means exceeding five parts per million were not observed until 1996 (year 2) from Remediated Zone 4 and Unremediated Zone 1, or until 1999 (year 5) at Unremediated Zone 2).

Again, the areas where sediment concentrations were high (> 5.0 ppm) did not include the entire width of the stream channel. Thus, the residual contamination remaining in Edmonds Creek is distributed in the similar uneven pattern shown by the pre-remediation data, but at lower concentrations.

Beyond the confines of the Edmonds Creek channel (throughout the marsh) pre-remediation concentrations ranged between "undetectable" to 4.6 ppm (see Figure 4-2). Hence, most of the contaminant was originally concentrated in the channel. Subsequent transport of residual PCBs from the marsh towards the channel following rain events may partially account for the concentrations presently observed in the unremediated zones.

3.2.5 Comparisons with data from the Remedial Action Report

Blasland, Bouck, & Lee (BBL) reported extensive sediment sampling, immediately prior to and after the remedial excavation (BBL 1996). Their document is entitled "Remedial Action Report, Kin-Buc Landfill, Operable Unit 2, Edison, New Jersey". BBL established a sampling design intended to define perimeters of each remediated zone that would enclose the areas where sediment concentrations exceeded five parts per million. Samples were first collected at the perimeter of each zone, established from the results of previous remedial design sampling. If these results produced values greater than five parts per million, additional sampling was conducted and the perimeters extended. Because sample locations were "targeted" for this specific purpose, the data produced lacked the randomness necessary to calculate representative sample means from each zone, and cannot be compared to 1999 means calculated by Normandeau Associates.

Analysis of 118 pre-excavation samples collected during September through November 1994 did identify particularly high concentrations from specific locations. Individual results as high as 229 and 104 ppm dry wt were reported from Zones 4 and 5, respectively (see Tables 4 and 5 in BBL 1996). Combining these results with results from the RIFS show that high PCB concentrations were present over the entire length of the study area prior to the remedial excavation. Analysis of 702 post-excavation "confirmatory" samples, collected from November 1994 to May 1995, produced a range of values between "undetectable" and 5.0 ppm (Tables 8 through 13 in BBL 1996); and confirmed the success of the remediation effort.

3.2.6 Comparisons with data from the Wetlands Restoration Monitoring Study

Here, data from a report entitled "Sixth semi-annual/October 1998 Wetlands Restoration Monitoring Progress Report, Kin-Buc Landfill, Operable Unit 2/ECMA (EMCON 1999) are used to supplement data collected by Normandeau Associates in 1999. In Appendix G (Table G-2) of this report EMCON presents sediment data from five sample locations (channel and bank) in each remediated zone (n = 25). The samples were collected in December 1998. The 1998 means are compared to the means obtained during August 1999 (n = 20). Pooled means that represent these two (most recent) sample dates combined are also presented. All results are given in parts per million dry weight.

Zone	1998 Mean	1999 Mean	Pooled Mean
Remediated Zone 1	1.6 (n = 5)	1.6 (n = 4)	1.6 (n = 9)
Remediated Zone 2	0.7 (n = 5)	1.2 (n = 4)	0.9 (n = 9)
Remediated Zone 3	1.0 (n = 5)	3.2 (n = 4)	1.9 (n = 9)
Remediated Zone 4	2.4 (n = 5)	6.4 (n = 4)	4.2 (n = 9)
Remediated Zone 5	3.5 (n = 5)	1.9 (n = 4)	2.8 (n = 9)

Assuming that sediment concentrations in each zone did not increase appreciably during January through July 1999, it can be shown that including additional data usually produced lower means from within the zones. Pooled means were lower than the 1999 means from Zones 3, 4, and 5, and the same in Zone 1. More importantly, the pooled mean of 4.2 ppm from Zone 4 was below the remediation standard. Samples were not collected from the unremediated zones as part of the wetlands restoration effort but, more likely, a larger data set would produce lower means there as well.

Table 1. Kin-Buc Project - Sediment PCB Data for 1999 Collections (year 5).

Sample ID Number	Sediment Concentration (µg/kg dry wt) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg dry wt)	Normalized sum of Aroclors (µg/g OC)	% Moisture	% OC	% Silt & Clay
Edmonds Creek Remediated Zone 1:												
A10+50R	6 U	14 U	16 U	12 U	478	285	103	**914**	33.9	71.6	2.7	85.0
A10+50L	55 U	135 U	160 U	120 U	2,030	1,280	230 J	**4,010**	267.3	70.7	1.5	88.1
A10+50/12+00	6 U	15 U	18 U	14 U	513	324	108	**998**	166.3	73.9	0.6	88.2
A12+50L	4 U	10 U	12 U	10 U	322	223	94	**675**	33.8	63.1	2.0	90.9
							Mean	**1,649**	125.3			
							Std. error of the mean	**789**	56.7			
							Coefficient of Variation	**95.8%**	90.5%			
Edmonds Creek Remediated Zone 2:												
A21+00L	4 U	10 U	12 U	10 U	676	492	177	**1,381**	106.2	62.3	1.3	92.2
A21+00/22+00	6 U	14 U	16 U	12 U	719	465	168	**1,400**	116.7	71.5	1.2	82.4
A22+00R	4 U	10 U	12 U	9 U	600	455	240	**1,330**	88.7	61.3	1.5	93.0
A22+50L	6 U	15 U	18 U	14 U	329	240	123	**745**	41.4	74.0	1.8	90.7
							Mean	**1,214**	88.2			
							Std. error of the mean	**157**	16.7			
							Coefficient of Variation	**25.9%**	37.8%			
Edmonds Creek Unremediated Zone 2:												
UN-ABEN-02R	39 U	95 U	110 U	85 U	800	620	108 J	**1,857**	116.1	57.9	1.6	93.5
UN-ABEN-02AL	215 U	500 U	600 U	460 U	29,200	10,400	2,300	**43,675**	7,279.2	62.0	0.6	93.1
UN-ABIO-02R	20 U	47 U	55 U	42 U	2,980	1,670	440	**5,254**	477.6	58.5	1.1	94.1
UN-ABIO-02/02A	180 U	420 U	500 U	375 U	9,200	3,500	1,180	**15,355**	2,193.6	53.6	0.7	47.4
							Mean	**16,535**	2,516.6			
							Std. error of the mean	**9,490**	1,650.9			
							Coefficient of Variation	**114.8%**	131.2%			

Table 1. continued.

Sample ID Number	Sediment Concentration (µg/kg dry wt) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg dry wt)	Normalized sum of Aroclors (µg/g OC)	% Moisture	% OC	% Silt & Clay
Edmonds Creek Remediated Zone 3:												
A31+25L	14 U	32 U	39 U	29 U	1,270	930	210	**2,524**	841.3	40.0	0.3	66.3
A31+25/32+25	26 U	60 U	70 U	55 U	2,330	1,850	360	**4,751**	395.9	67.9	1.2	82.8
A33+00R	8 U	20 U	24 U	18 U	920	1,250	176	**2,416**	241.6	61.9	1.0	96.3
A33+00L	15 U	36 U	42 U	32 U	1,250	790	250	**2,415**	603.8	45.5	0.4	97.3
							Mean	**3,026**	520.6			
							Std. error of the mean	**575**	130.1			
							Coefficient of Variation	**38.0%**	50.0%			
Edmonds Creek Remediated Zone 4:												
A42+25R	50 U	120 U	145 U	110 U	5,060	2,310	600	**8,395**	599.6	68.0	1.4	86.9
A42+25/46+50	85 U	205 U	245 U	185 U	7,920	4,590	620 J	**13,850**	1,259.1	61.8	1.1	85.5
A42+25/46+50 Dup	42 U	100 U	120 U	90 U	5,430	2,620	560	**8,962**	1,120.2	60.9	0.8	75.0
A46+75R	8 U	18 U	22 U	17 U	829	441	150	**1,485**	185.6	58.3	0.8	95.4
A46+75L	20 U	47 U	55 U	42 U	2,440	1,330	420	**4,354**	435.4	58.7	1.0	95.8
							Mean	**6,410**	602.6			
							Std. error of the mean	**2,187**	213.4			
							Coefficient of Variation	**68.2%**	70.8%			
Edmonds Creek Remediated Zone 5:												
A50+50L	7 U	16 U	20 U	14 U	846	859	127	**1,889**	472.2	52.4	0.4	94.7
A51+00R	20 U	47 U	55 U	42 U	870	1,080	179	**2,293**	254.8	58.5	0.9	96.4
A51+00/52+00	19 U	45 U	55 U	40 U	1,440	730	210	**2,539**	1,269.5	56.7	0.2	90.2
A52+50R	3 U	8 U	9 U	7 U	366	242	99	**734**	91.8	49.6	0.8	96.4
							Mean	**1,864**	237.1			
							Std. error of the mean	**400**	85.8			
							Coefficient of Variation	**42.9%**	72.3%			

Table 1. continued.

Sample ID Number	Sediment Concentration (µg/kg dry wt) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg dry wt)	Normalized sum of Aroclors (µg/g OC)	% Moisture	% OC	% Silt & Clay
Edmonds Creek Unremediated Zone 1:												
UN-ABEN-01L	18 U	43 U	50 U	38 U	2,810	3,010	580	**6,549**	545.8	54.8	1.2	92.3
UN-ABEN-01AR	18 U	43 U	50 U	39 U	2,970	2,430	490	**6,040**	1,208.0	54.9	0.5	93.5
UN-ABIO-01AL	33 U	80 U	95 U	70 U	5,180	3,140	670	**9,268**	712.9	50.3	1.3	91.6
UN-ABIO-01/01A	35 U	85 U	100 U	75 U	2,520	1,290	271 J	**4,376**	726.0	52.8	0.6	80.7
							Mean	**6,558**	798.2			
							Std. error of the mean	**1,015**	142.6			
							Coefficient of Variation	**31.0%**	35.7%			
Reference Creek Zone 1:												
RA-ABEN-01L	4 U	8 U	10 U	8 U	131	250	115	**526**	52.6	53.8	1.0	94.8
RA-ABEN-01AR	4 U	10 U	12 U	9 U	191	286	130	**642**	91.7	61.3	0.7	93.3
RA-ABEN-01AL	4 U	10 U	12 U	9 U	166	238	118	**557**	61.9	60.4	0.9	93.8
RA-ABIO-01/01A	5 U	10 U	13 U	10 U	295	286	215	**834**	52.1	63.6	1.6	95.1
RA-ABIO-01/01A Dup	5 U	12 U	14 U	10 U	270	266	114	**691**	49.4	67.2	1.4	91.7
							Mean	**622**	64.2			
							Std. error of the mean	**53**	9.5			
							Coefficient of Variation	**17.0%**	29.5%			
Reference Creek Zone 2:												
RA-ABEN-02L	3 U	8 U	10 U	8 U	66	82	35 J	**212**	30.3	52.1	0.7	96.0
RA-ABEN-02AR	3 U	8 U	9 U	7 U	62	79	29 J	**197**	65.7	49.7	0.3	97.4
RA-ABEN-02AL	5 U	11 U	13 U	10 U	142	199	92	**472**	42.9	64.5	1.1	95.1
RA-ABIO-02/02A	4 U	10 U	12 U	10 U	245	248	110	**639**	63.9	63.2	1.0	95.1
							Mean	**380**	50.7			
							Std. error of the mean	**107**	8.5			
							Coefficient of Variation	**56.3%**	33.7%			

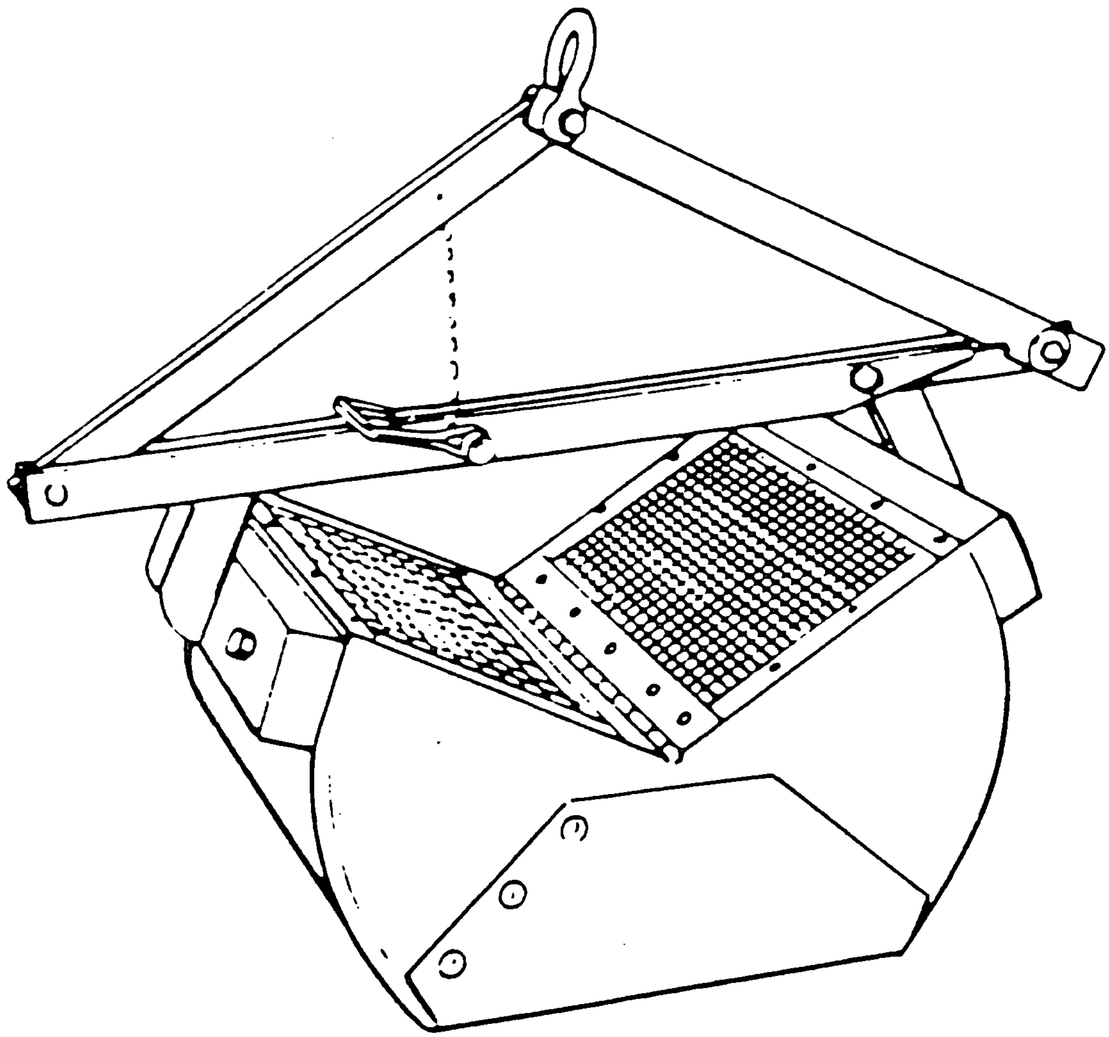
Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Table 2. Kin-Buc Project - Sediment Grain Size Data for 1999 Collections (year 5).

Sample ID Number	% Gravel	% Sand	% Silt	% Clay	% Silt + Clay
Edmonds Creek Remediated Zone 1:					
A10+50R	0.0	15.0	62.8	22.2	85.0
A10+50L	0.0	11.9	64.0	24.1	88.1
A10+50/12+00	0.0	11.8	64.1	24.1	88.2
A12+50L	0.0	9.1	58.3	32.6	90.9
Edmonds Creek Remediated Zone 2:					
A21+00L	0.8	7.0	62.1	30.1	92.2
A21+00/22+00	0.8	16.8	55.4	27.0	82.4
A22+00R	0.0	7.0	60.9	32.1	93.0
A22+50L	0.0	9.3	62.1	28.6	90.7
Edmonds Creek Unremediated Zone 2:					
UN-ABEN-02R	0.1	6.4	58.3	35.2	93.5
UN-ABEN-02AL	0.0	6.9	61.2	31.9	93.1
UN-ABIO-02R	0.0	5.9	61.4	32.7	94.1
UN-ABIO-02/02A	0.2	52.4	35.0	12.4	47.4
Edmonds Creek Remediated Zone 3:					
A31+25L	0.9	33.7	44.1	22.2	66.3
A31+25/32+25	0.4	16.8	60.9	21.9	82.8
A33+00R	0.0	3.7	61.6	34.7	96.3
A33+00L	0.1	2.7	65.1	32.2	97.3
Edmonds Creek Remediated Zone 4:					
A42+25R	0.0	13.1	63.4	23.5	86.9
A42+25/46+50	0.0	14.5	60.2	25.3	85.5
A42+25/46+50 Dup	0.1	24.9	54.0	21.0	75.0
A46+75R	0.1	4.5	69.6	25.8	95.4
A46+75L	0.0	4.2	70.7	25.1	95.8
Edmonds Creek Remediated Zone 5:					
A50+50L	0.1	5.2	69.4	25.3	94.7
A51+00R	0.0	3.6	74.6	21.8	96.4
A51+00/52+00	0.0	9.8	69.9	20.3	90.2
A52+50R	0.0	3.6	63.3	33.1	96.4

Table 2. continued.

Sample ID Number	% Gravel	% Sand	% Silt	% Clay	% Silt + Clay
Edmonds Creek Unremediated Zone 1:					
UN-ABEN-01L	0.0	7.7	70.5	21.8	92.3
UN-ABEN-01AR	0.0	6.5	68.3	25.2	93.5
UN-ABIO-01AL	0.0	8.4	66.1	25.5	91.6
UN-ABIO-01/01A	0.8	18.5	53.4	27.3	80.7
Reference Creek Zone 1:					
RA-ABEN-01L	0.0	5.2	69.5	25.3	94.8
RA-ABEN-01AR	0.0	6.7	66.0	27.3	93.3
RA-ABEN-01AL	0.0	6.2	73.6	20.2	93.8
RA-ABIO-01/01A	0.0	4.9	68.5	26.6	95.1
RA-ABIO-01/01A Dup	0.0	8.3	71.9	19.8	91.7
Reference Creek Zone 2:					
RA-ABEN-02L	0.0	4.0	64.9	31.1	96.0
RA-ABEN-02AR	0.0	2.6	60.5	36.9	97.4
RA-ABEN-02AL	0.0	4.9	74.0	21.1	95.1
RA-ABIO-02/02A	0.0	4.9	70.2	24.9	95.1



NORMANDEAU ASSOCIATES ENVIRONMENTAL CONSULTANTS 3450 Schuylkill Road Spring City, PA 19475-1124	FIGURE 2 PONAR GRAB	DATE:	12-17-96
		JOB NO.:	16148.001
		SCALE:	NOT TO SCALE

Figure 3. Approximate location of PCB sampling stations.

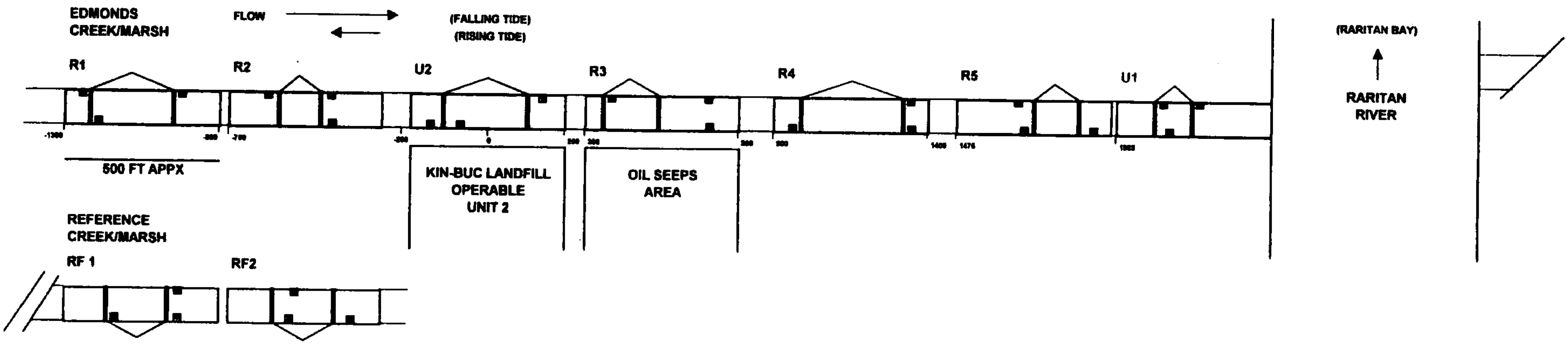
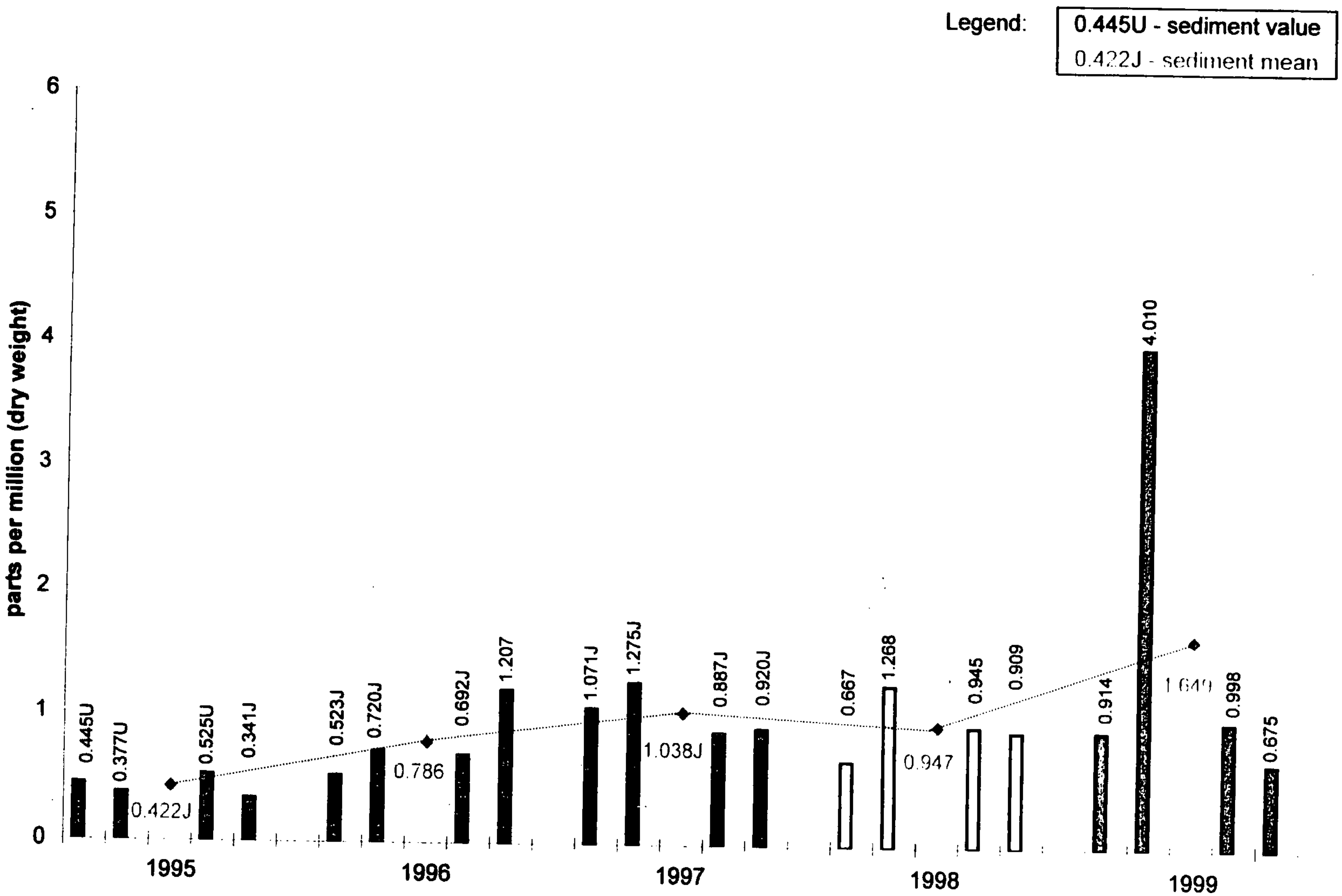
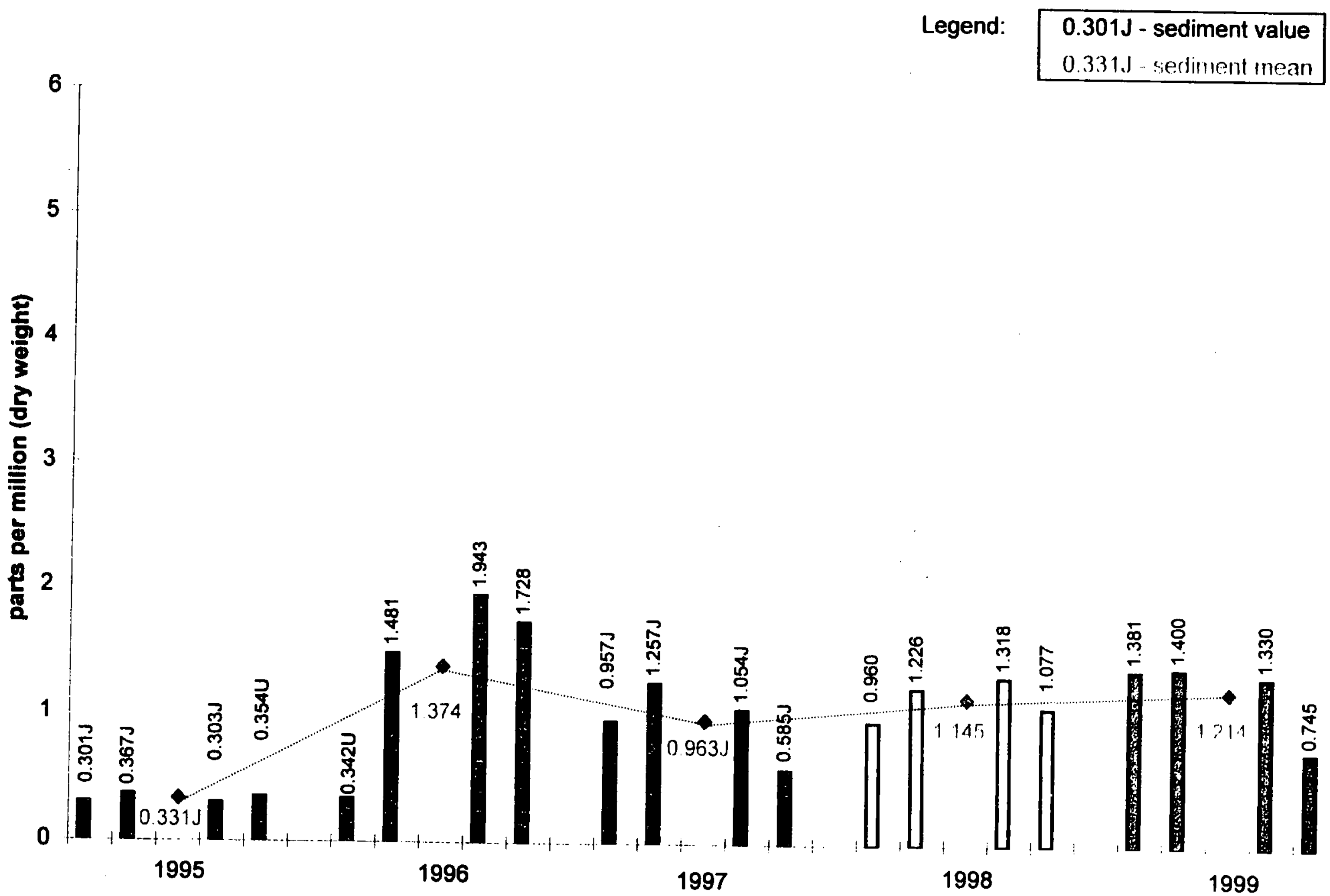


Figure 4. Five year PCB trend for sediment samples collected from Remediated Zone 1 near Kin-Buc Landfill.



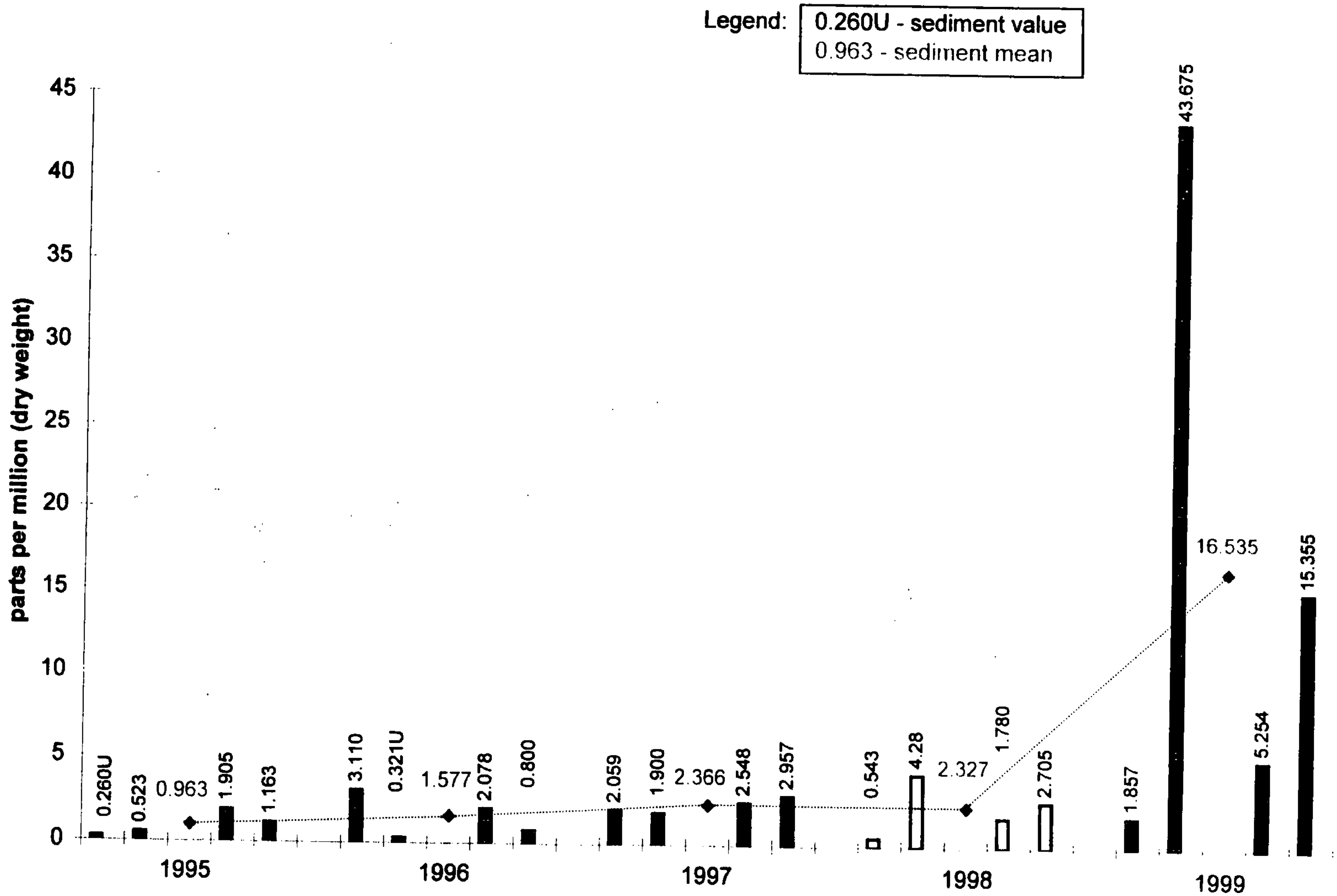
Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 5. Five year PCB trend for sediment samples collected from Remediated Zone 2 near Kin-Buc Landfill.



Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 6. Five year PCB trend for sediment samples collected from Unremediated Zone 2 near Kin-Buc Landfill.



Notes: 1) One-half detection limit was assumed for U-qualified data.

Figure 7. Five year PCB trend for sediment samples collected from Remediated Zone 3 near Kin-Buc Landfill.

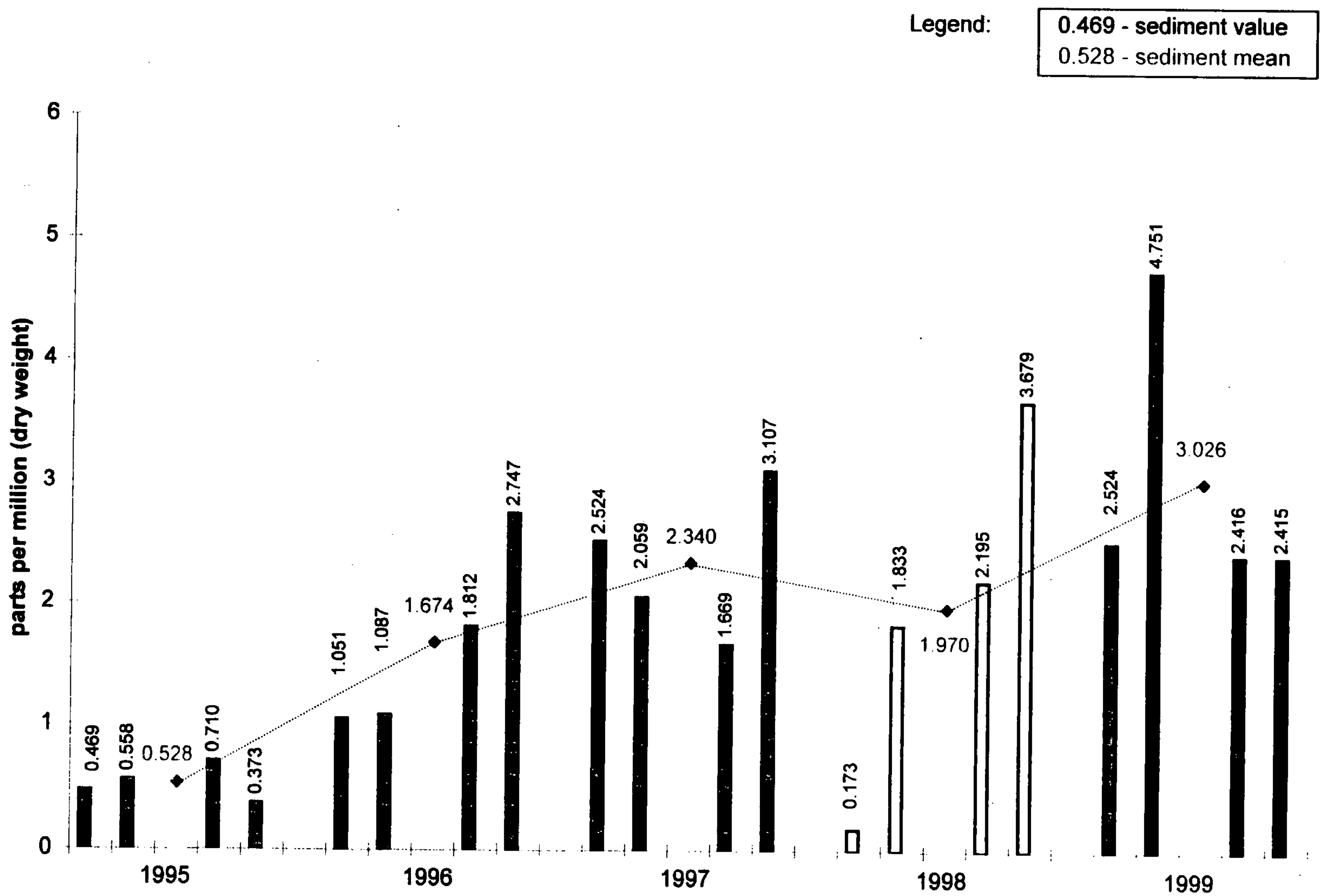


Figure 8. Five year PCB trend for sediment samples collected from Remediated Zone 4 near Kin-Buc Landfill.

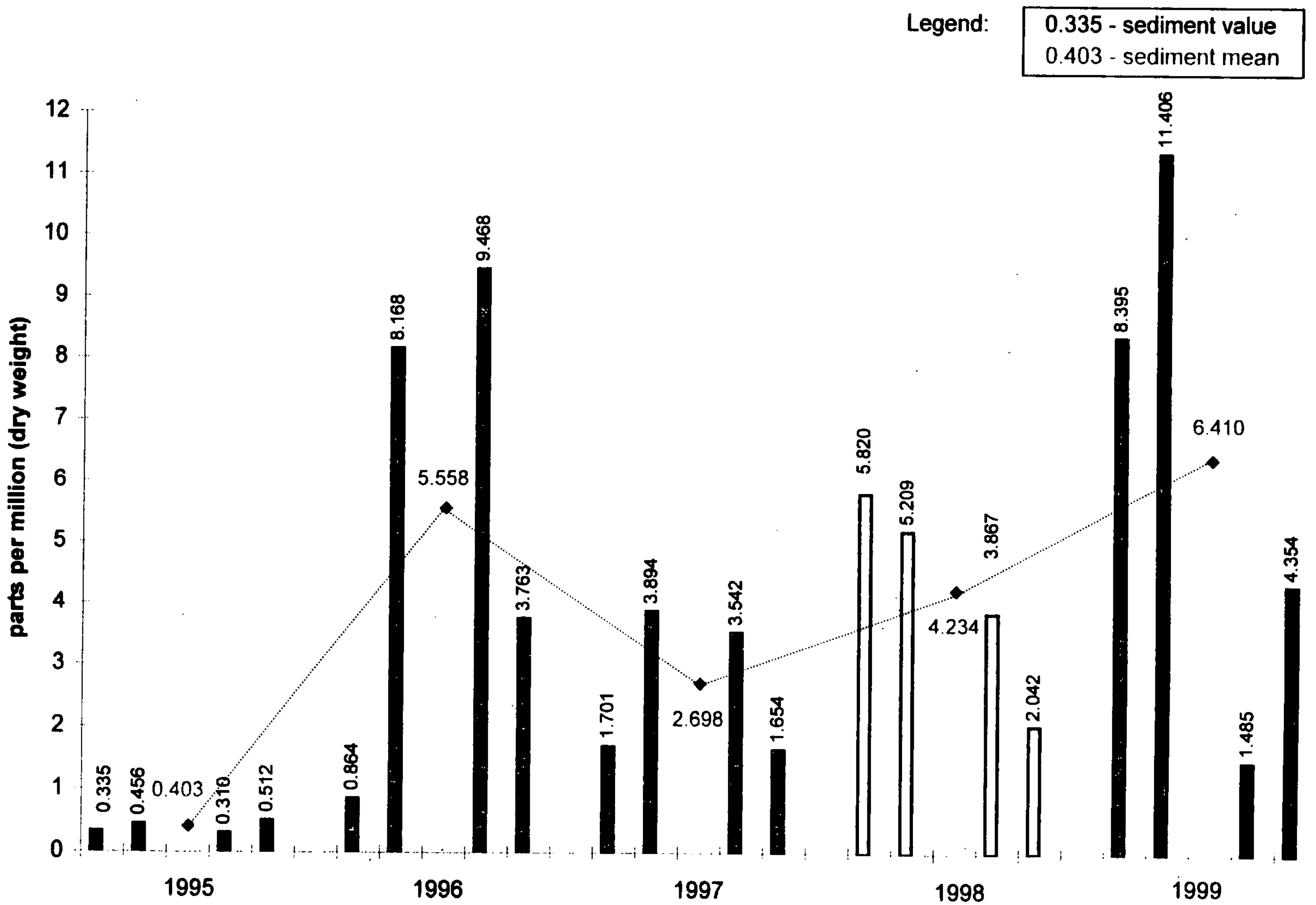
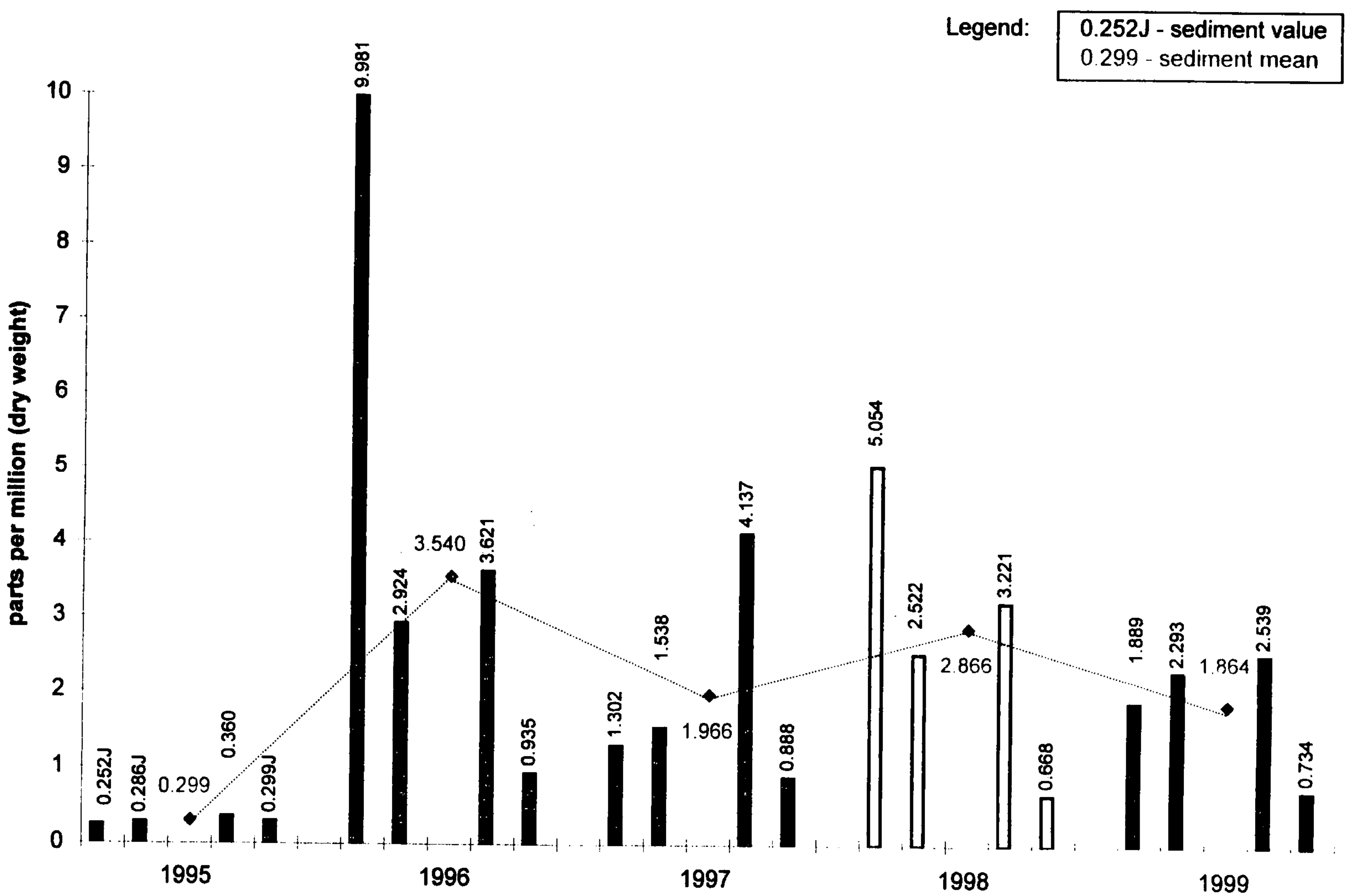
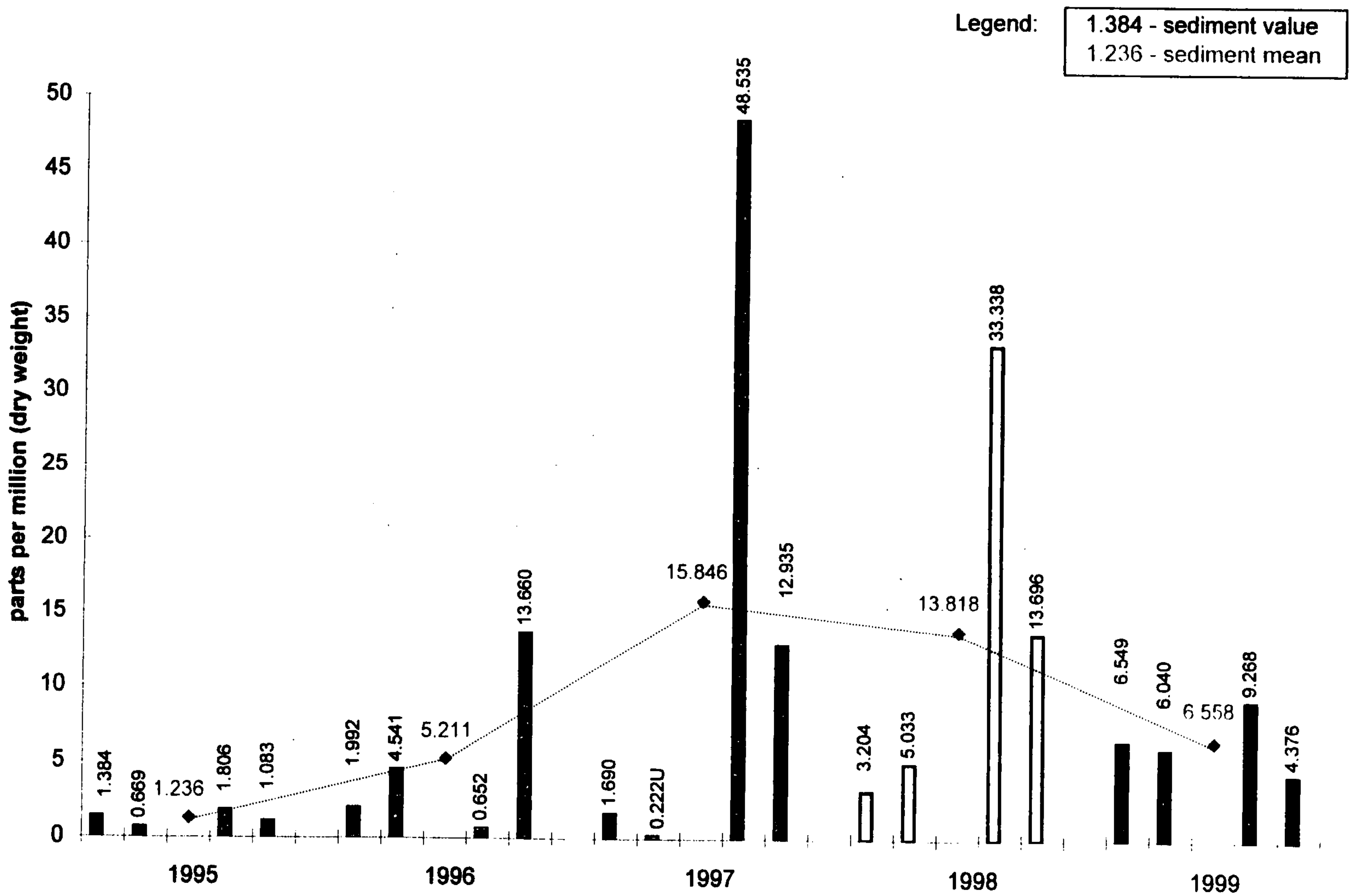


Figure 9. Five year PCB trend for sediment samples collected from Remediated Zone 5 near Kin-Buc Landfill.



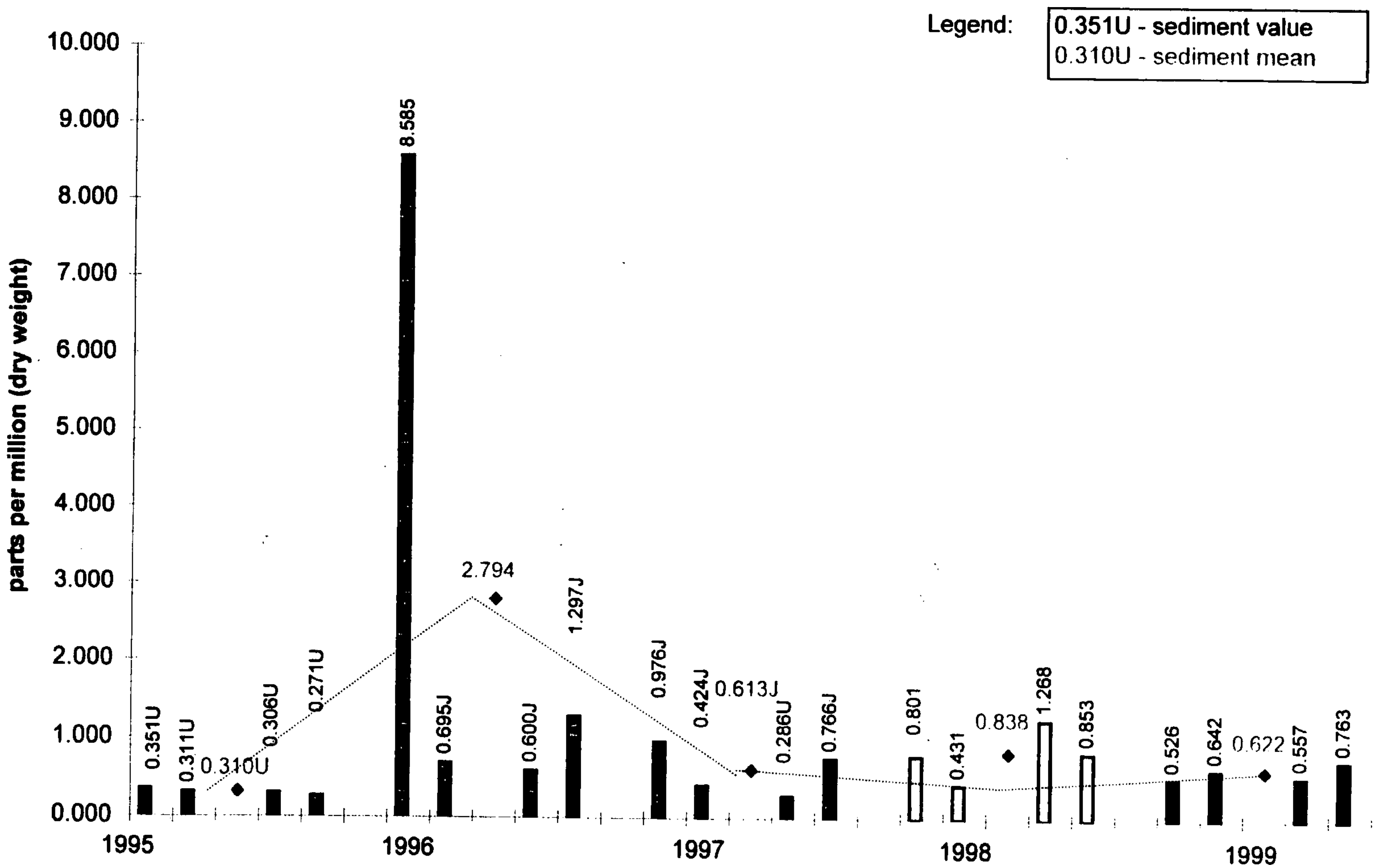
Notes: 1) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 10. Five year PCB trend for sediment samples collected from Unremediated Zone 1 near Kin-Buc Landfill.



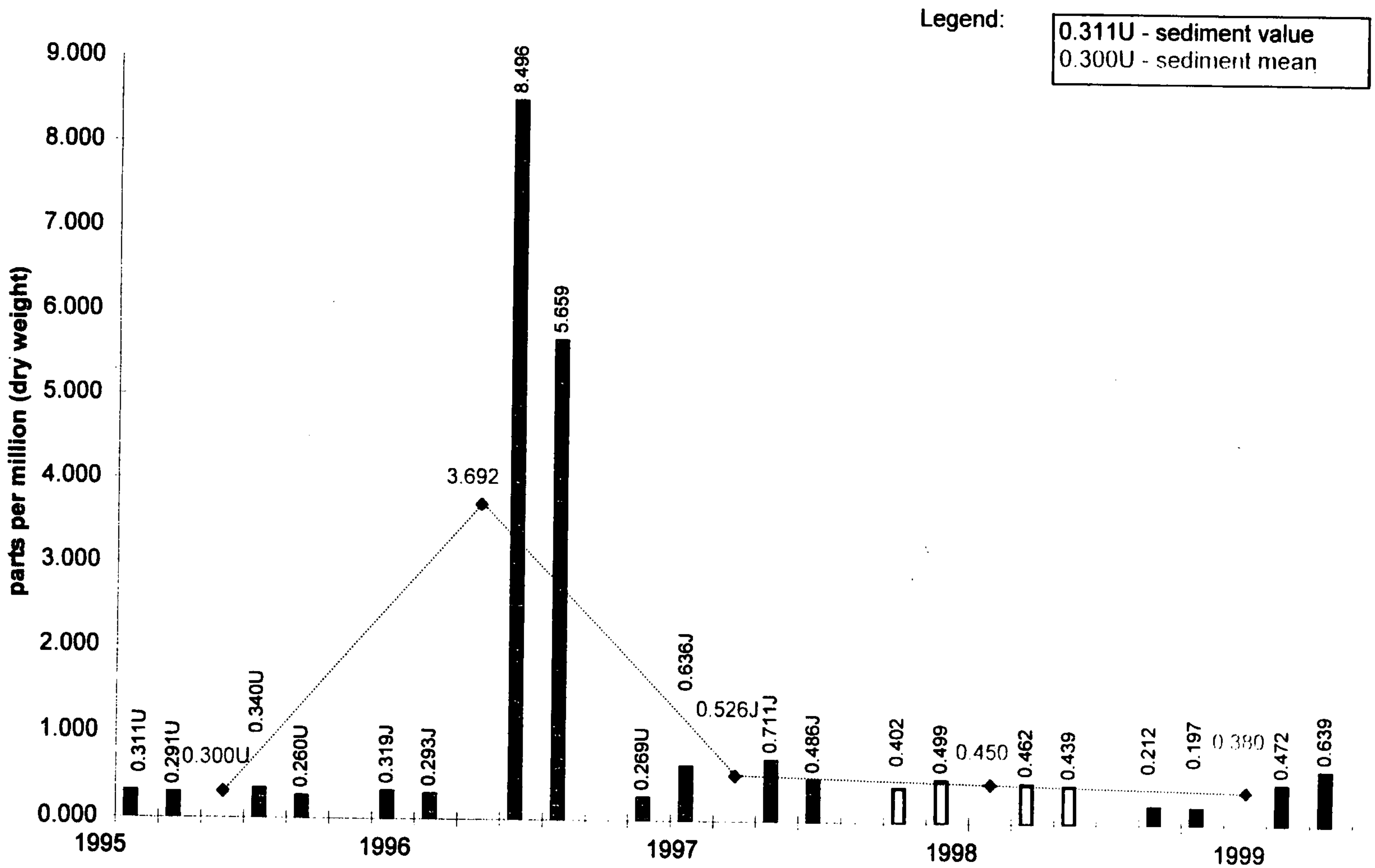
Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 11. Five year PCB trend for sediment samples collected from Reference Zone 1 near Kin-Buc Landfill.

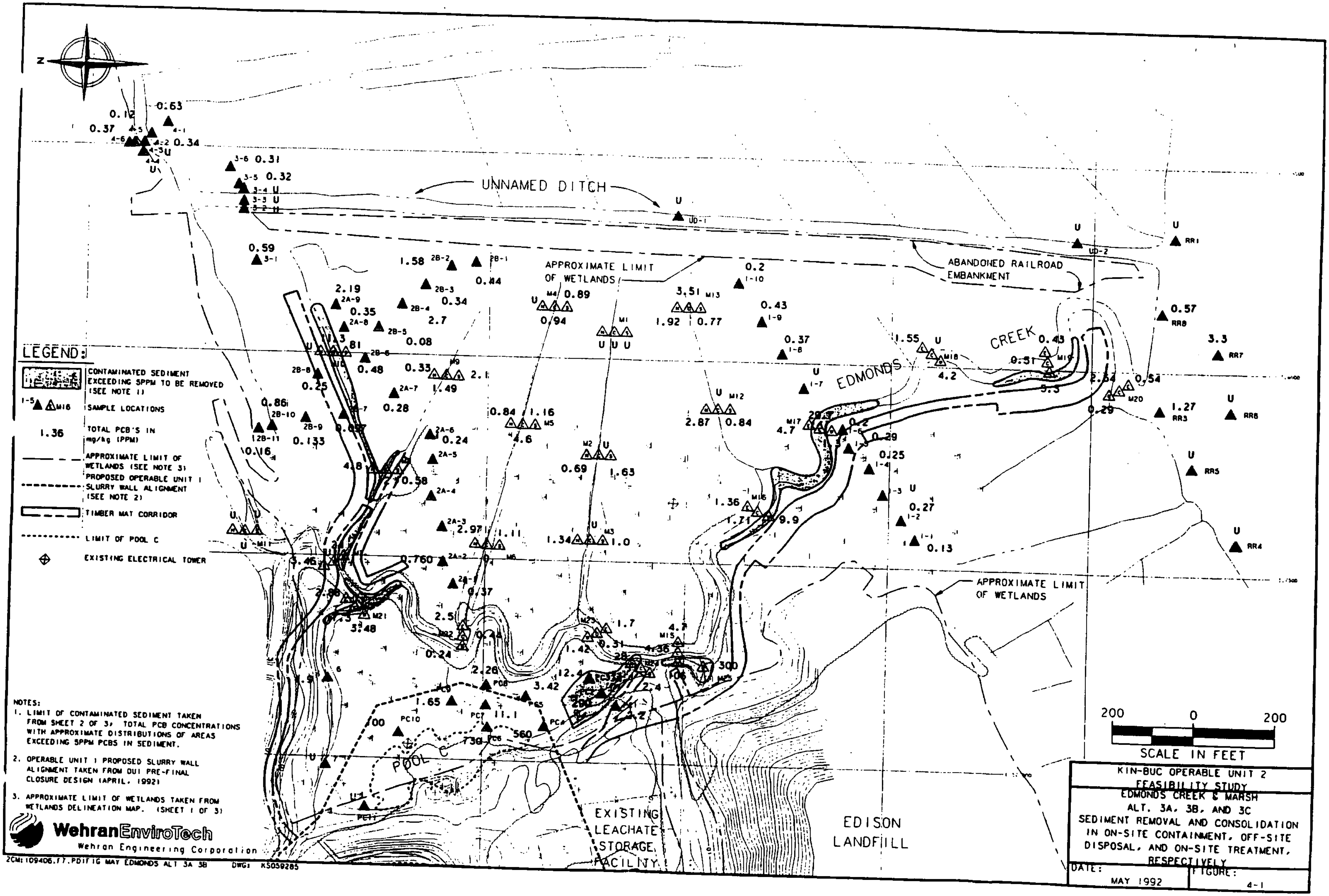


Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 12. Five year PCB trend for sediment samples collected from Reference Zone 2 near Kin-Buc Landfill.



Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.



UNNAMED DITCH
APPROXIMATE LIMIT OF WETLANDS
ABANDONED RAILROAD EMBANKMENT
EDMONDS CREEK
POOL C
EXISTING LEACHATE STORAGE FACILITY
EDISON LANDFILL
LEGEND:
CONTAMINATED SEDIMENT EXCEEDING 5PPM TO BE REMOVED (SEE NOTE 1)
SAMPLE LOCATIONS
TOTAL PCB'S IN mg/kg (PPM)
APPROXIMATE LIMIT OF WETLANDS (SEE NOTE 3)
PROPOSED OPERABLE UNIT 1 SLURRY WALL ALIGNMENT (SEE NOTE 2)
TIMBER MAT CORRIDOR
LIMIT OF POOL C
EXISTING ELECTRICAL TOWER
NOTES:
1. LIMIT OF CONTAMINATED SEDIMENT TAKEN FROM SHEET 2 OF 3; TOTAL PCB CONCENTRATIONS WITH APPROXIMATE DISTRIBUTIONS OF AREAS EXCEEDING 5PPM PCBS IN SEDIMENT.
2. OPERABLE UNIT 1 PROPOSED SLURRY WALL ALIGNMENT TAKEN FROM OU1 PRE-FINAL CLOSURE DESIGN (APRIL, 1992)
3. APPROXIMATE LIMIT OF WETLANDS TAKEN FROM WETLANDS DELINEATION MAP. (SHEET 1 OF 3)
WehranEnviroTech
Wehran Engineering Corporation
200 0 200
SCALE IN FEET
KIN-BUC OPERABLE UNIT 2 FEASIBILITY STUDY
EDMONDS CREEK & MARSH
ALT. 3A, 3B, AND 3C
SEDIMENT REMOVAL AND CONSOLIDATION IN ON-SITE CONTAINMENT, OFF-SITE DISPOSAL, AND ON-SITE TREATMENT, RESPECTIVELY
DATE: MAY 1992
FIGURE: 4-1
2CM:109406.F7.PDIFIG MAY EDMONDS ALT 3A 3B DWG: K5059285

4.0 FIDDLER CRAB TISSUE ANALYSIS

Brackish water fiddler crabs were selected as a target organism for PCB analysis because they are relatively immobile and thus useful for assessing localized impacts. Brackish water fiddler crabs are discernible from other local species of fiddler crabs by the presence of a transverse groove on the carapace behind each eye. They feed mainly upon bacteria, minute algae, and decomposing plant material gleaned from the mud. Natural burrowers, fiddler crabs are in constant contact with marsh sediments and thus subject to PCB exposure throughout their lifespans.

4.1 Materials and Methods

Collection

Crabs were collected from 30 August through 2 September 1999 from seven Edmonds Creek and two Reference Creek zones. Crabs were captured from locations as close to the corresponding sediment sample points as possible. These locations are shown on Drawings 1 and 1.5. A total of twenty-seven tissue samples (plus two field duplicates) was collected from the two marsh systems. Fifteen were collected from remediated zones (three per zone), six from unremediated zones, and six from zones in the reference area. Specimens were hand-captured by digging them out of their burrows and their identity confirmed. The samples were then segregated into those consisting of big (> 10 grams) and small (< 8 grams) individuals. One sample consisting of only male specimens was collected from each zone. Male specimens were easily discerned from females in the field by the shape of the telson (narrow in males, rounded and wider in females). Prior to transport to the laboratory for analyses of PCBs and lipids, the specimens were rinsed with distilled water to remove adhering sediment, placed in aluminum foil, enclosed in zip-loc bags, and frozen.

The samples were analyzed according to US EPA Method 8082 (US EPA, 1992). Lipids were analyzed according to AOAC, Procedure 948.15 (AOAC,1990). PCB results were normalized to percent lipid concentrations according to the formula:

$$\text{PCB concentration } (\mu g/g \text{ lipid}) = \frac{\text{PCB concentration } (\mu g/kg)}{\% \text{ lipid} \times 10}$$

and the analytical results reported both as micrograms/kilogram wet weight (whole body burden) and micrograms/gram lipid (normalized). The data were described with the same set of statistics used for the sediment samples.

4.2 Results and Discussion

The results of the PCB analysis for fiddler crab tissue samples are presented in Table 3 and are arrayed in same fashion as the sediment data. Concentrations for seven Aroclors are presented first, followed by the total PCB concentrations expressed as wet weight and the lipid normalized concentrations, respectively. Quality control results, Laboratory Analysis Reports and Field Data Sheets are provided in Appendix B.

Comparisons between the samples consisting of big verses small specimens are shown below. Here, results are given as the Sum of Aroclors (wet weight) in parts per million:

Edmonds Creek Zones	"Big" Samples	"Small" Samples
Remediated Zone 1	0.297	0.919
Remediated Zone 2	0.707 (males)	1.584 (average)
Unremediated Zone 2	0.577	2.053
Remediated Zone 3	0.919	2.143
Remediated Zone 4	1.167	2.063
Remediated Zone 5	0.191	1.166
Unremediated Zone 1	0.358 (average)	2.783
Reference Creek Zones		
Reference Zone 1	0.056	0.137
Reference Zone 2	0.068	0.155

In each case the results showed the smaller individuals to be accumulating PCBs to a greater extent. In six of eight instances the 1998 results showed the smaller individuals to be accumulating PCBs to a greater extent. Prior to 1998 the results were inconclusive.

Comparisons between samples consisting of male only specimens versus samples consisting of both males and females are given below. Note that all "male only" samples were produced using big individuals. Also note that the majority of the fiddler crabs in both creeks are males (from approximately 60 to 90 percent at particular zones based on field observations). Thus the samples containing both sexes are largely comprised of males. Not withstanding, the sample results from 1997 (the first year this comparison was made) showed higher whole body burdens within these "mixed" samples. Thus, 1997 results suggested that females were accumulating PCBs to the greater extent. The 1998 results were inconclusive as similar whole body concentrations were observed in five of nine sample pairs. Two zones produced higher concentrations from the mixed samples and two zones produced higher results from the male only samples. Again, results are given as the Sum of Aroclors (wet weight) in parts per million.

Edmonds Creek Zones	"Big Male/Female" Samples	"Big Male only" Samples
Remediated Zone 1	0.297	0.694
Remediated Zone 2	–	0.707
Unremediated Zone 2	0.577	1.853
Remediated Zone 3	0.919	2.236
Remediated Zone 4	1.167	0.736
Remediated Zone 5	0.191	0.353 (average)
Unremediated Zone 1	0.358 (average)	1.251
Reference Creek Zones		
Reference Zone 1	0.056	0.049
Reference Zone 2	0.068	0.121

The 1999 results contradicted results from 1997. In each case samples consisting of male only samples produced higher values.

4.2.1 Edmonds Creek Zones

Three Aroclors (1248, 1256, and 1260) were detected in samples collected from the Edmonds Creek zones. Aroclors 1248 and 1254 were the most prevalent. Concentrations for Aroclors 1248 and 1254 ranged from 55 to 1,500 μg/kg wet wt in individual samples. Less concentrated was Aroclor 1260 that ranged from 30 to 320 μg/kg wet wt.

Whole body burdens ranged from 191 to 2,236 μg/kg wet wt (0.191 and 2.236 ppm) in individual samples. Mean PCB concentrations within respective zones ranged from 570 (Remediated Zone 5) to 1,766 (Remediated Zone 3) μg/kg wet wt. Results from the tissue samples produced a different spatial pattern than that observed from the sediment samples. In short, sample zones with the highest sediment means did not necessarily produce the highest tissue means. The lowest values, near 0.6 ppm, were detected from Remediated Zones 1 and 5. Mean concentrations at the remaining zones were fairly consistent ranging between 1.3 to 1.7 ppm. Interestingly, the high in PCB concentration observed at Station UN-ABEN-02R (48.675 ppm) in Unremediated Zone 2 from the sediment analysis was not repeated at Station UN-CBEN-O2RALBM (1.853 ppm) for the fiddler crab analysis. This result suggests that the area where the sediment is most contaminated within Unremediated Zone 2 is localized.

Lipid normalized values in individual samples ranged from 36.1 to 264.7 μg/g lipid. Within particular zones mean concentrations ranged from 67.8 (Remediated Zone 5) to 183.5 (Unremediated Zone 2) μg/g lipid.

4.2.2 Reference Creek Zones

Expected results were obtained from Reference Creek where the lowest whole body concentrations were anticipated. Aroclors 1248, 1254, and 1260 were also detected there at nominal concentrations. Values for these Aroclors ranged from 2 (U) to 60 μg/g lipid.

When summed, the whole body burden concentrations ranged from 49 (J) to 155 μg/kg wet wt (0.049 J and 0.155 ppm) in individual samples. The results were very consistent. Mean values per zone were 81 μg/kg wet wt at Zone 1 and 115 μg/kg wet wt at Zone 2; near 0.1 ppm in each case. These data showed that the Reference Area fiddlers were less contaminated than those at Edmonds Creek and that the data should provide a good basis of comparison to analyze temporal trends.

Following lipid normalization the total PCB concentrations measured from individual tissue samples ranged from 6.2 to 22.1 μg/g lipid. By zone, sample means were 9.9 μg/g lipid at Zone 1 and 22.1 μg/g lipid at Zone 2.

4.2.3 Five Year Trend

Edmonds Creek Zones

The results of the PCB trend analysis for the fiddler crab tissue samples collected from Edmonds Creek are shown as Figures 13 through 19. Whole sediment means, calculated from three corresponding sample points per zone, are shown with the individual tissue values and tissue means. In an analogous fashion to the sediment trend analysis, whole body burden results are emphasized.

Encouraging results were obtained from three of seven zones where tissue means trended downward during the course of this study. In two additional zones sample means from year 5 were nearly the same as means from year 1. Slight increases were observed in two zones. Also, note that marked increases in sediment concentrations at specific sampling points, particularly those measured during 1997 and 1998 at Unremediated Zone 1 (UN-ABIO-01AL), and at Unremediated Zone 2 (mentioned above) did not induce gross increases in corresponding fiddler crab values.

Within zones annual changes in tissue means followed annual fluctuations in corresponding sediment means fairly well. Although within-zone means were generally higher nearest OU2, the temporal trends within particular zones did not display any pattern associated with their proximity to the landfill. Tissue means ranged between less than 1 to less than 4 ppm within all zones each year and were usually below 2 ppm.

Remediated Zone 1

Mean tissue concentrations have remained essentially the same over the course of the monitoring effort and were usually less than 1 ppm. A 1995 mean of 0.673 ppm was followed by means of 1.315 (1996), 0.636 (1997), 0.461 (1998), and 0.637 (1999) ppm (Figure 13). In general the tissue means were close to the corresponding sediment means. Also, intra-zone changes in sediment means from year to year were generally followed similar changes in the tissue means.

Remediated Zone 2

From 1995 to 1997 tissue means remained stable; and then increased slightly in 1998 and 1999. The tissue means were 0.654 (1995), 0.715 (1996), 0.587 (1997), 1.432 (1998), and 1.292 (1999) ppm (Figure 14). Each year the tissue means were fairly close to the corresponding sediment means. Annual changes in tissue means followed similar changes in corresponding sediment means producing a consistent trend between the two matrices.

Unremediated Zone 2

During the five year period mean PCB concentrations were 1.961 (1995), 2.463 (1996), 1.996 (1997), 2.604 (1998), and 1.494 (1999) ppm (Figure 15). Thus, the body burdens have trended downward during the course of the study. Tissue means were fairly close to corresponding sediment means during the first four years of monitoring but then diverged in 1999.

Remediated Zone 3

At Remediated Zone 3, fiddler crab body burdens remained essentially unchanged from 1995 to 1999 although fairly substantial annual fluctuations were observed. A 1995 mean of 1.632 ppm increased to 3.765 ppm in 1996 and 3.219 ppm in 1997 (Figure 16). In 1998 the mean fell to a four year low of 1.348 ppm. The 1999 mean was 1.766 ppm, very near the 1995 mean. Tissue and sediment means followed similar temporal trends.

Remediated Zone 4

A slight increase in body burden was observed at Remediated Zone 4. Low annual means of 1.017 (1995) and 0.941 (1996) were followed by means of 2.412 (1997) and 1.624 (1998) ppm (Figure 17). In 1999 a mean of 1.322 ppm was slightly above the 1995 mean. Corresponding sediment means were very close to the tissue means only in 1995 and 1997. In 1998 and 1999 increases in the sediment means were accompanied by a decrease in tissue means. Similarly the trends between the two matrices diverged in 1996, 1998, and 1999. These results suggest that increases in sediment concentration at Zone 4 during 1998 were not the result of widespread contamination.

Remediated Zone 5

During the course of the monitoring effort tissue means trended downward at Zone 5. The tissue results produced a temporal pattern similar to that observed at Remediated Zone 3 although the means were lower and annual changes not as pronounced. Tissue means were 1.151 (1995), 1.662 (1996), 1.316 (1997), 0.747 (1998), and 0.570 (1999) ppm (Figure 18). Thus, the 1999 mean was approximately one-half that from 1995. The corresponding sediment mean was close in value to the tissue mean only in 1997 and 1999, again suggesting that the sediment concentrations reported were the result of a localized contamination.

Unremediated Zone 1

The least consistent results obtained during the study were observed at Unremediated Zone 1. There, the sediment means increased considerably between 1996 and 1997 while the tissue means trended downward. Annual tissue means of 1.905 and 2.322 ppm in 1995 and 1996, respectively, decreased by nearly 1 ppm to 1.052 ppm in 1996 and 1.188 ppm in 1998 (Figure 19). In 1999 the tissue mean decreased to 1.464, nearly one-half a part per million less than the 1995 mean. Conversely, corresponding sediment means were 16.816 ppm in 1997 and 13,858 ppm in 1998. These results suggested that PCB contamination was not evenly distributed throughout the zone. The 1997 and 1998 data showed the contamination to be localized in an area along the right shoreline (facing downstream) approximately 250 feet from the confluence of Edmonds Creek with the Raritan River. In 1999 the corresponding sediment mean was much lower - 7.286 ppm.

Reference Creek Zones

The trends in fiddler crab whole body burdens within the Reference Creek zones are shown in Figures 20 and 21. These values were below 0.5 ppm throughout the study period and, in a similar fashion to Edmonds Creek, were not influenced by what appeared to be local increases in sediment concentrations observed during 1996. By zone, 1995 to 1999 sample means were 0.157, 0.128, 0.270, 0.119, and 0.081 ppm at Reference Zone 1, and 0.168, 0.124, 0.437, 0.163, and 0.115 ppm at Reference Zone 2.

4.2.4 Comparisons with data from the Remedial Investigation/Feasibility Study

During August 1990, US EPA collected three fiddler crab samples from Edmonds Creek for PCB analysis (see Appendix A in Wehran 1992). Two samples were collected from Remediated Zone 3 ("Upper Edmonds Creek") and one sample (plus a field duplicate) was collected from Unremediated Zone 1 ("Lower Edmonds Creek"). Results were 1.0 ppm and 14.0 ppm (wet weight) from Remediated Zone 3 and 0.4 ppm (wet weight) from Unremediated Zone 1. The highest result from Unremediated Zone 3 was obtained near the discharge from the area referred to as "Pool C", where some of the highest sediment concentrations were found before the remediation. The highest single tissue result from this monitoring effort was 5.8 ppm (from Remediated Zone 3 in 1996). No other individual result from Zone 3 (or any of the other zones) exceeded 3.8 ppm in any year. The pre-remediation data from the RIFS are limited but suggest that body burdens in the crab tissues have been reduced since the remediation.

Table 3. Kin-Buc Project - Fiddler Crab Tissue PCB Concentrations from 1999 Samples (year 5).

Sample ID Number	PCB Tissue Concentration (µg/kg wet weight)							Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
	A1016	A1221	A1232	A1242	A1248	A1254	A1260			
Edmonds Creek Remediated Zone 1:										
C10+50RB	2 U	6 U	7 U	6 U	149	97	30	297	59.4	0.5
C10+50LS	5 U	12 U	14 U	10 U	383	382	113	919	83.5	1.1
C12+50LBM	5 U	12 U	14 U	10 U	351	230	72	694	77.1	0.9
							Mean	637	73.3	
							Std. error of the mean	181	7.2	
							Coefficient of Variation	49.4%	17.0%	
Edmonds Creek Remediated Zone 2:										
C21+00LS	14 U	30 U	35 U	26 U	1,050	690	190	2,035	135.7	1.5
C22+00RS	5 U	12 U	14 U	10 U	627	352	114	1,134	126.0	0.9
C22+50LBM	5 U	12 U	14 U	10 U	394	213	59	707	58.9	1.2
							Mean	1,292	106.9	
							Std. error of the mean	391	24.1	
							Coefficient of Variation	52.5%	39.1%	
Edmonds Creek Unremediated Zone 2:										
UN-CBEN-02RB	5 U	12 U	14 U	10 U	281	191	64	577	57.7	1.0
UN-CBEN-02ALBM	12 U	30 U	35 U	26 U	1,030	580	140	1,853	264.7	0.7
UN-CBIO-02RS	12 U	30 U	35 U	26 U	990	730	230	2,053	228.1	0.9
							Mean	1,494	183.5	
							Std. error of the mean	462	63.8	
							Coefficient of Variation	53.6%	60.2%	

Table 3. continued.

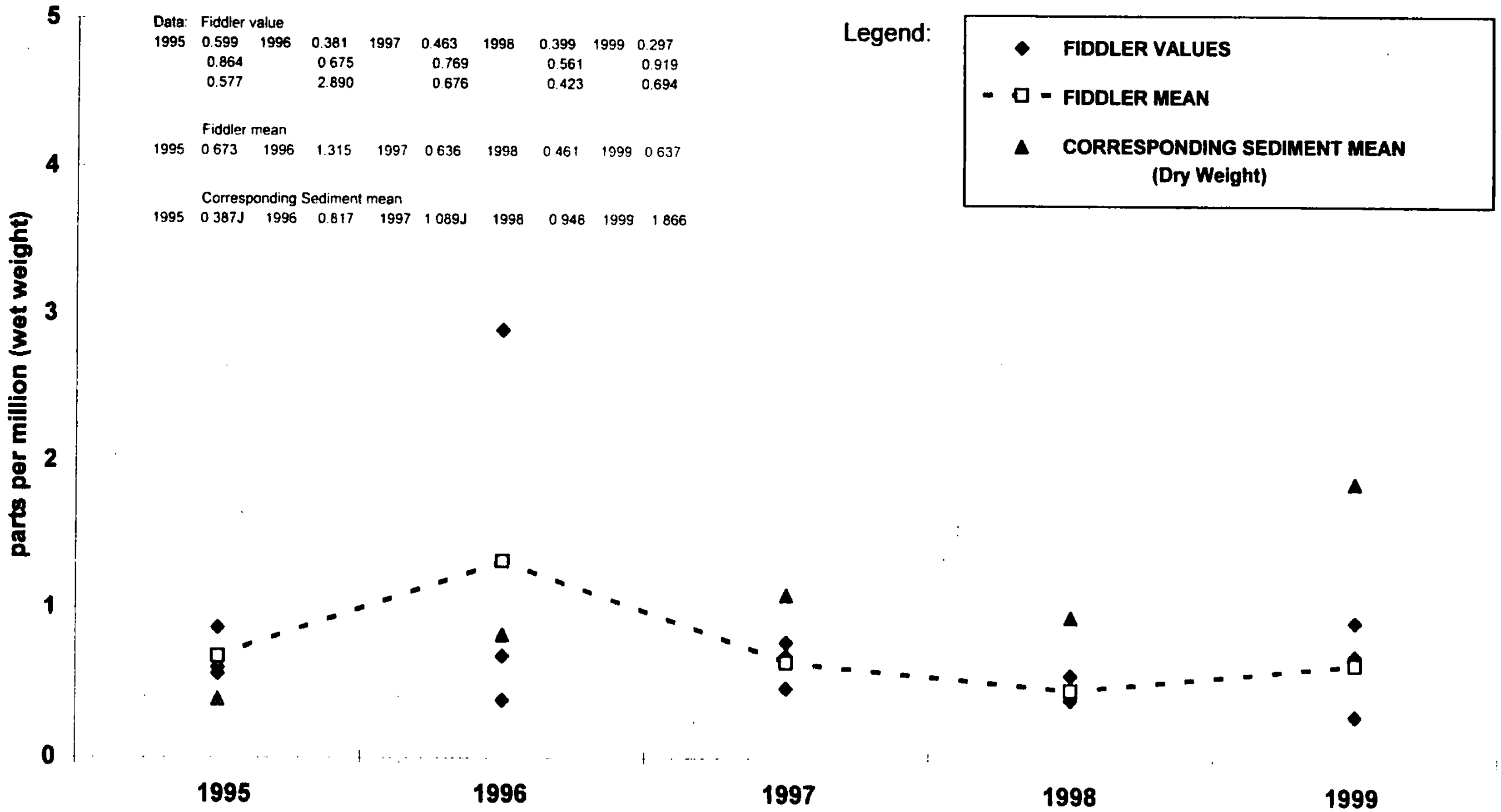
Sample ID Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Remediated Zone 3:										
C31+25LS	12 U	30 U	35 U	26 U	1,210	670	160	2,143	164.8	1.3
C33+00RB	5 U	12 U	14 U	10 U	541	261	76	919	183.8	0.5
C33+00LBM	12 U	30 U	35 U	26 U	1,500	520	113 J	2,236	159.7	1.4
							Mean	1,766	169.4	
							Std. error of the mean	424	7.3	
							Coefficient of Variation	41.6%	7.5%	
Edmonds Creek Remediated Zone 4:										
C42+25RB	5 U	12 U	14 U	10 U	710	316	100	1,167	116.7	1.0
C46+75RS	12 U	30 U	35 U	26 U	1,320	500	140	2,063	158.7	1.3
C46+75LBM	5 U	12 U	14 U	10 U	357	253	85	736	61.3	1.2
							Mean	1,322	112.2	
							Std. error of the mean	391	28.2	
							Coefficient of Variation	51.2%	43.5%	
Edmonds Creek Remediated Zone 5:										
C50+50LBM	5 U	12 U	14 U	10 U	188	136	52	417	41.7	1.0
C50+50LBM Dup	5 U	12 U	14 U	10 U	109	97	42 J	289	36.1	0.8
C51+00RB	5 U	12 U	14 U	10 U	72	55	23 J	191	47.8	0.4
C52+50RS	12 U	30 U	35 U	26 U	630	330	103 J	1,166	116.6	1.0
							Mean	570	67.8	
							Std. error of the mean	302	24.6	
							Coefficient of Variation	91.7%	62.7%	

Table 3. continued.

Sample ID Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Unremediated Zone 1:										
UN-CBEN-01LB	5 U	12 U	14 U	10 U	155	142	49 J	387	38.7	1.0
UN-CBEN-01LB Dup	5 U	12 U	14 U	10 U	137	112	40 J	330	47.1	0.7
UN-CBEN-01ARBM	12 U	30 U	35 U	26 U	630	400	118 J	1,251	178.7	0.7
UN-CBIO-01ALS	12 U	30 U	35 U	26 U	1,320	1,040	320	2,783	173.9	1.6
							Mean	1,464	131.8	
							Std. error of the mean	708	44.5	
							Coefficient of Variation	83.8%	58.5%	
Reference Creek Zone 1:										
RA-CBEN-01LBM	2 U	6 U	7 U	6 U	6 U	2 U	20 J	49 J	9.8	0.5
RA-CBEN-01ARB	2 U	6 U	7 U	6 U	6 U	2 U	27	56	6.2	0.9
RA-CBEN-01ALS	2 U	6 U	7 U	6 U	25 J	54	37	137	13.7	1.0
							Mean	81	9.9	
							Std. error of the mean	28	2.2	
							Coefficient of Variation	60.4%	37.9%	
Reference Creek Zone 2:										
RA-CBEN-02LB	2 U	6 U	7 U	6 U	6 U	25 J	16 J	68 J	13.8	0.5
RA-CBEN-02ARS	2 U	6 U	7 U	6 U	42	60	32	155	22.1	0.7
RA-CBEN-02ALBM	2 U	6 U	7 U	6 U	30	46	24 J	121	20.2	0.6
							Mean	115	18.7	
							Std. error of the mean	25	2.5	
							Coefficient of Variation	38.1%	23.3%	

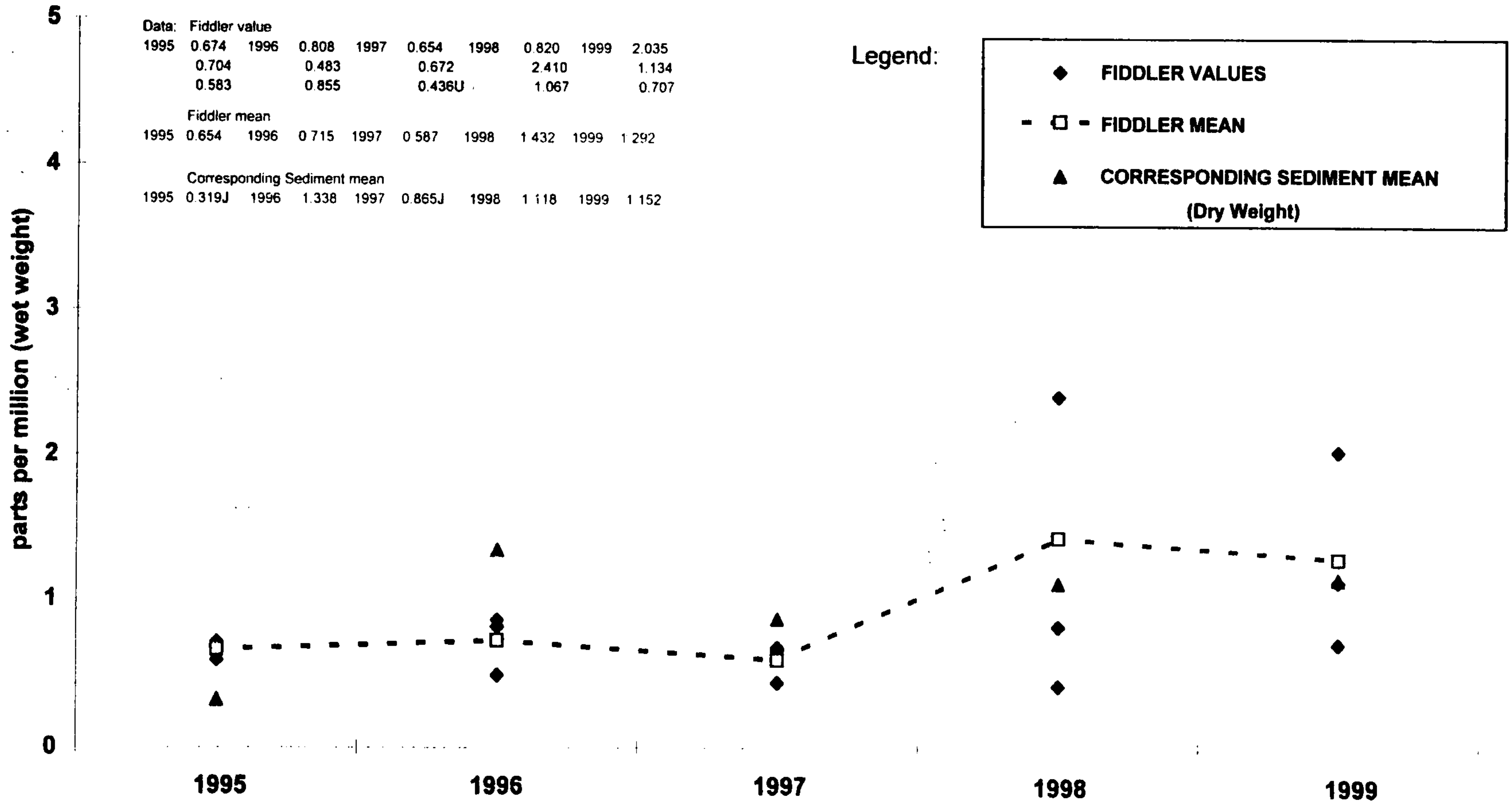
Notes: 1) One-half detection limit was assumed for all U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantification are J-qualified.

Figure 13. Five year PCB trend for fiddler crab tissue samples collected from Remediated Zone 1 near Kin-Buc Landfill.



Notes: 1) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 14. Five year PCB trend for fiddler crab tissue samples collected from Remediated Zone 2 near Kin-Buc Landfill.



Notes: 1)One-half detection limit was assumed for U-qualified data.

2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 15. Five year PCB trend for fiddler crab tissue samples collected from Unremediated Zone 2 near Kin-Buc Landfill.

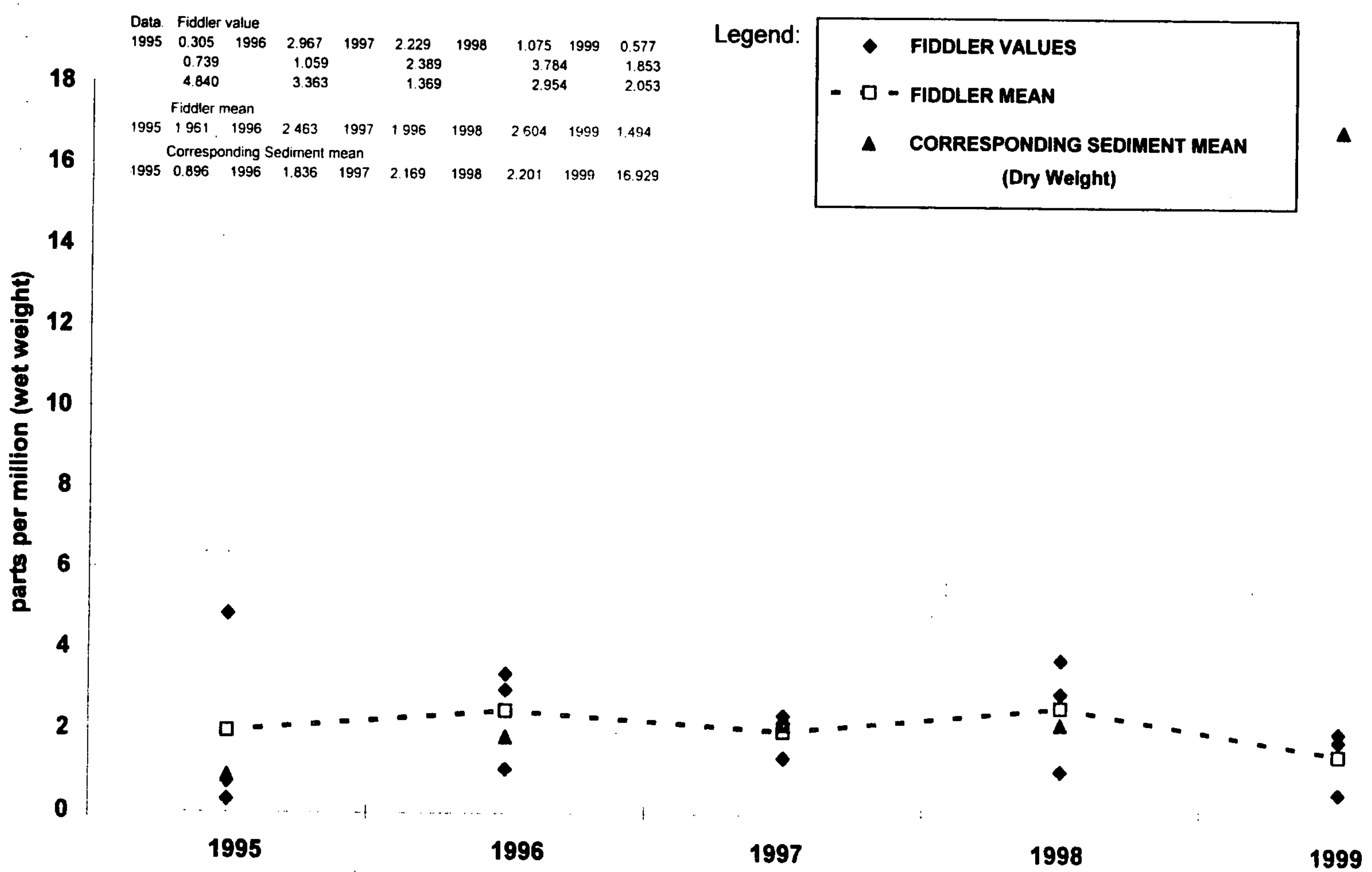


Figure 16. Five year PCB trend for fiddler crab tissue samples collected from Remediated Zone 3 near Kin-Buc Landfill.

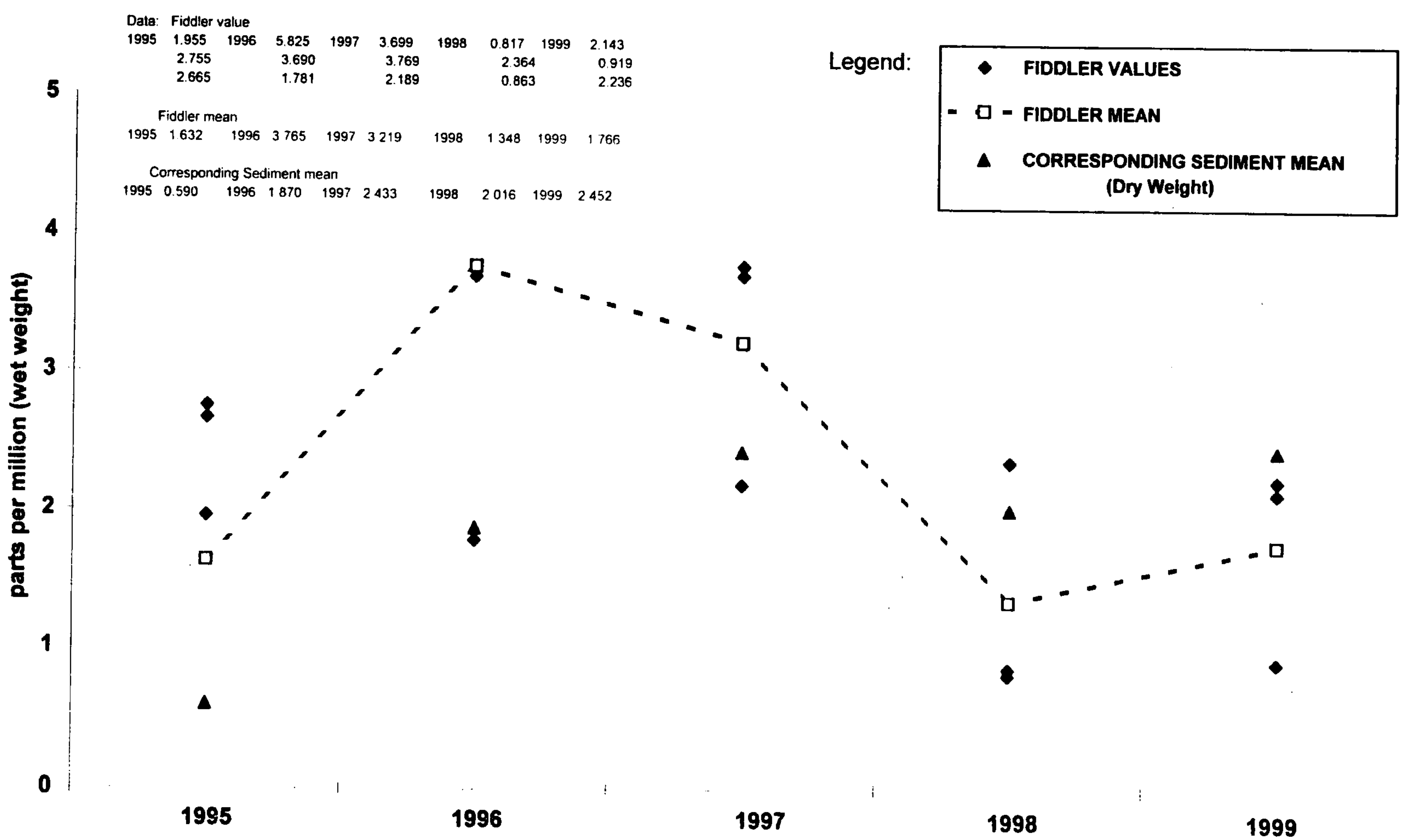


Figure 17. Five year PCB trend for fiddler crab tissue samples collected from Remediated Zone 4 near Kin-Buc Landfill.

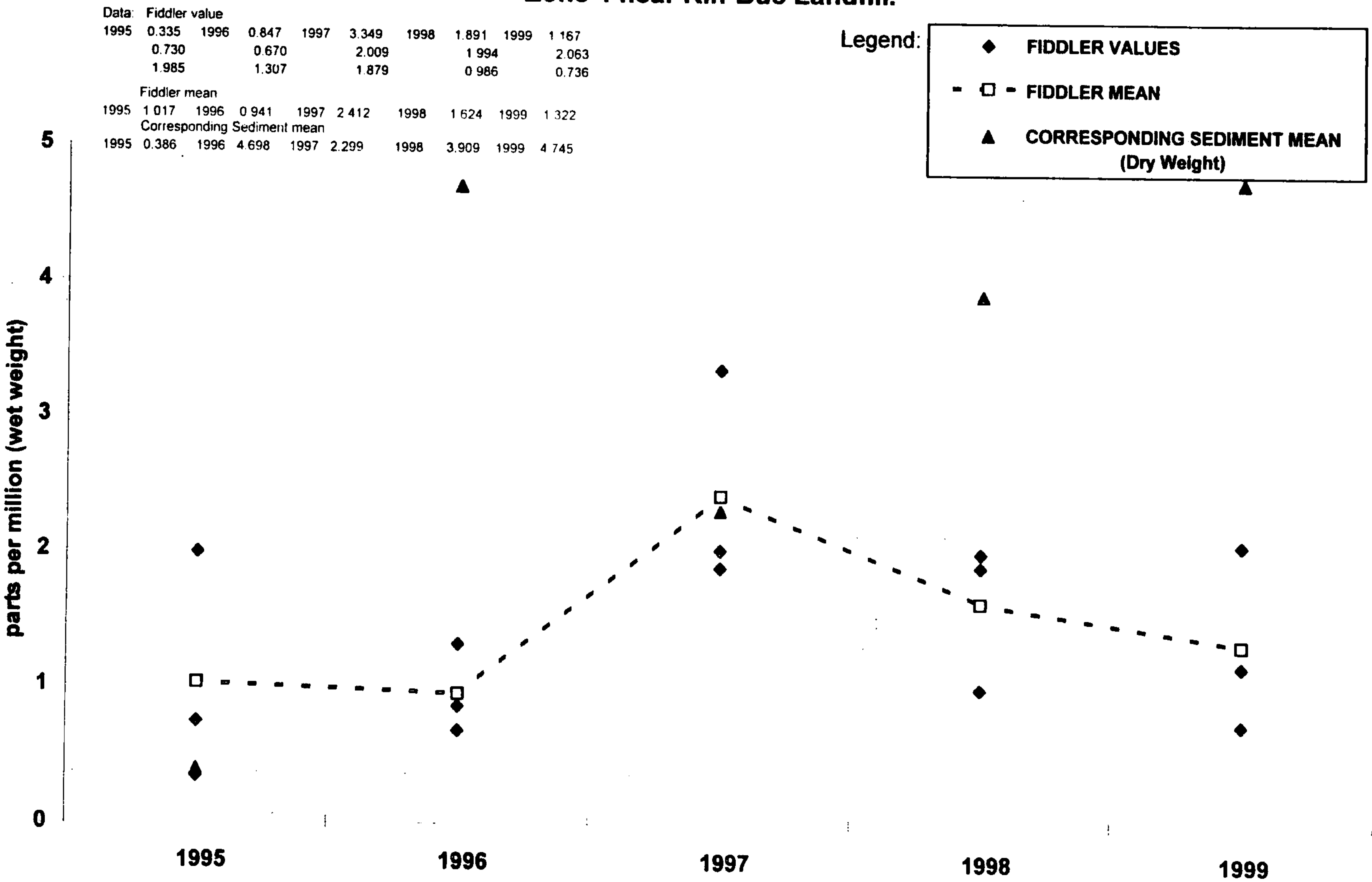
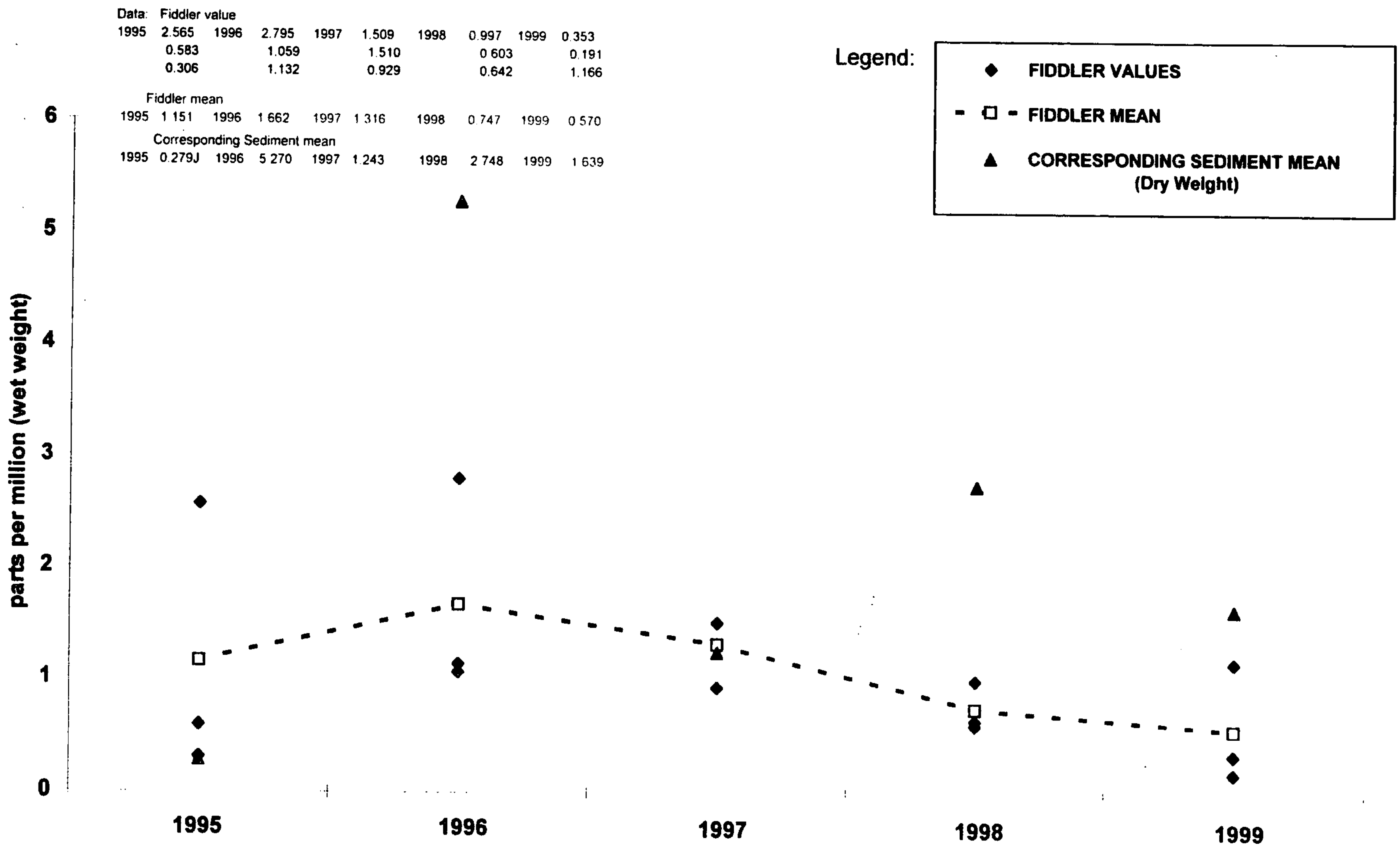


Figure 18. Five year PCB trend for fiddler crab tissue samples collected from Remediated Zone 5 near Kin-Buc Landfill.



Notes: 1) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 19. Five year PCB trend for fiddler crab tissue samples collected from Unremediated Zone 1 near Kin-Buc Landfill.

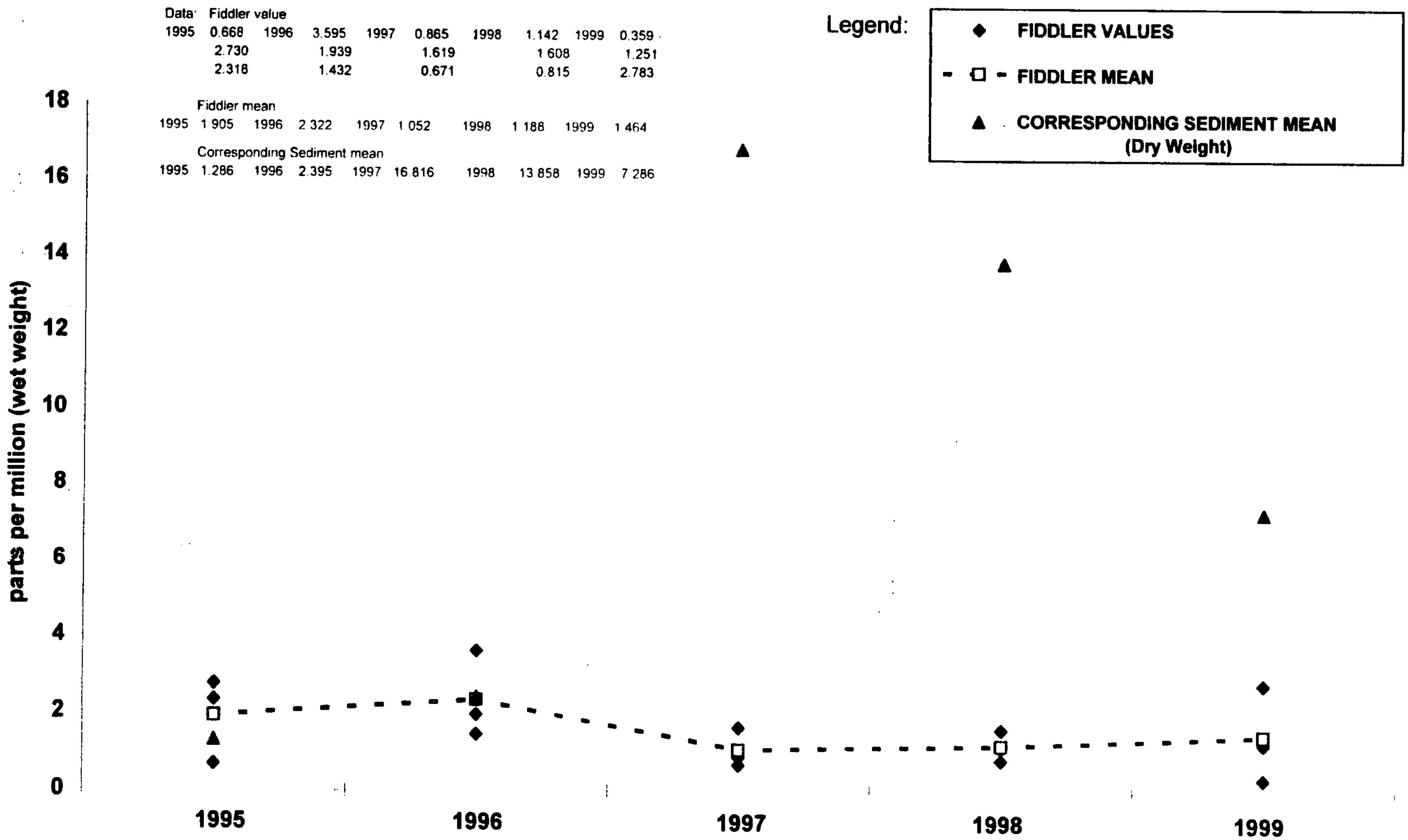
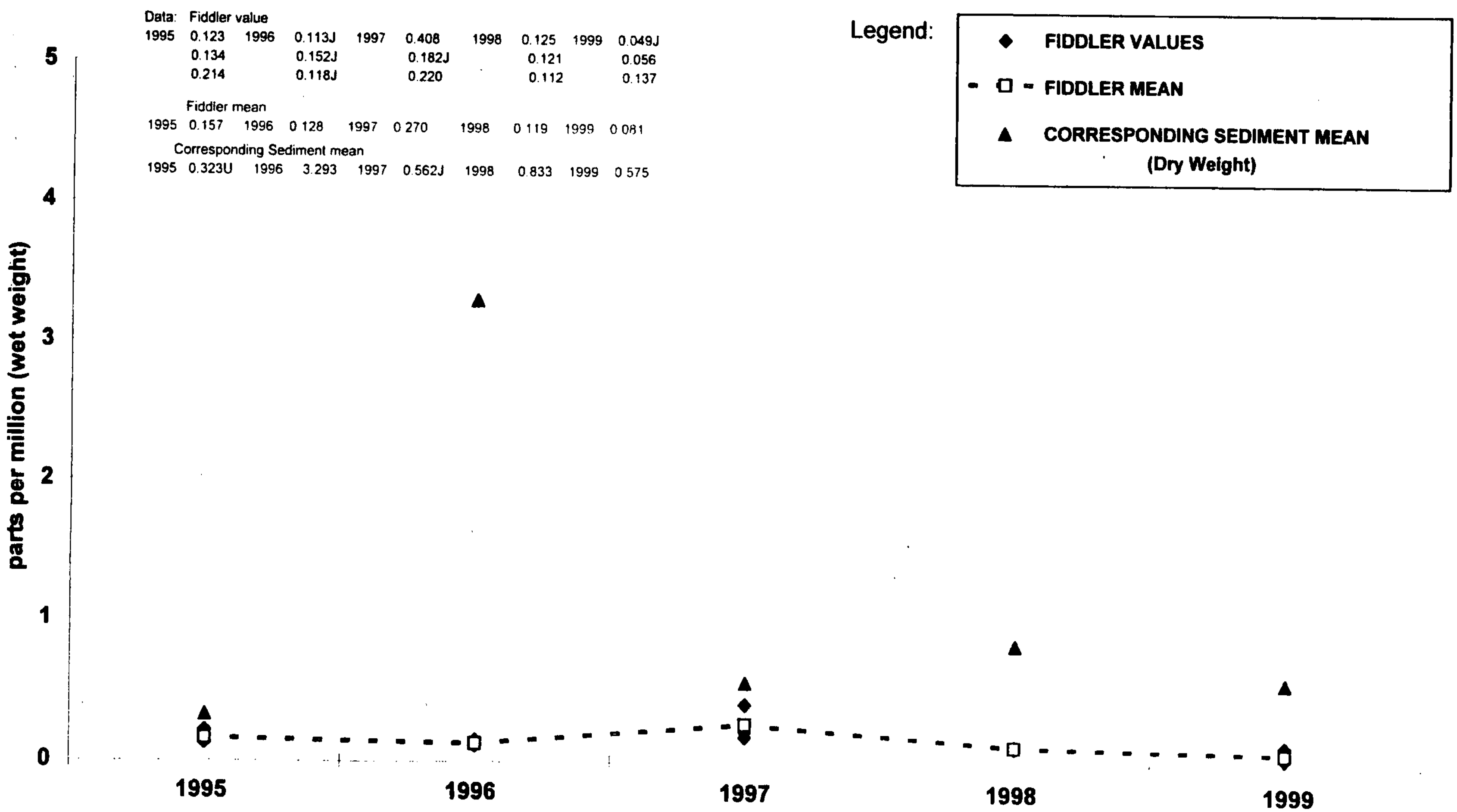
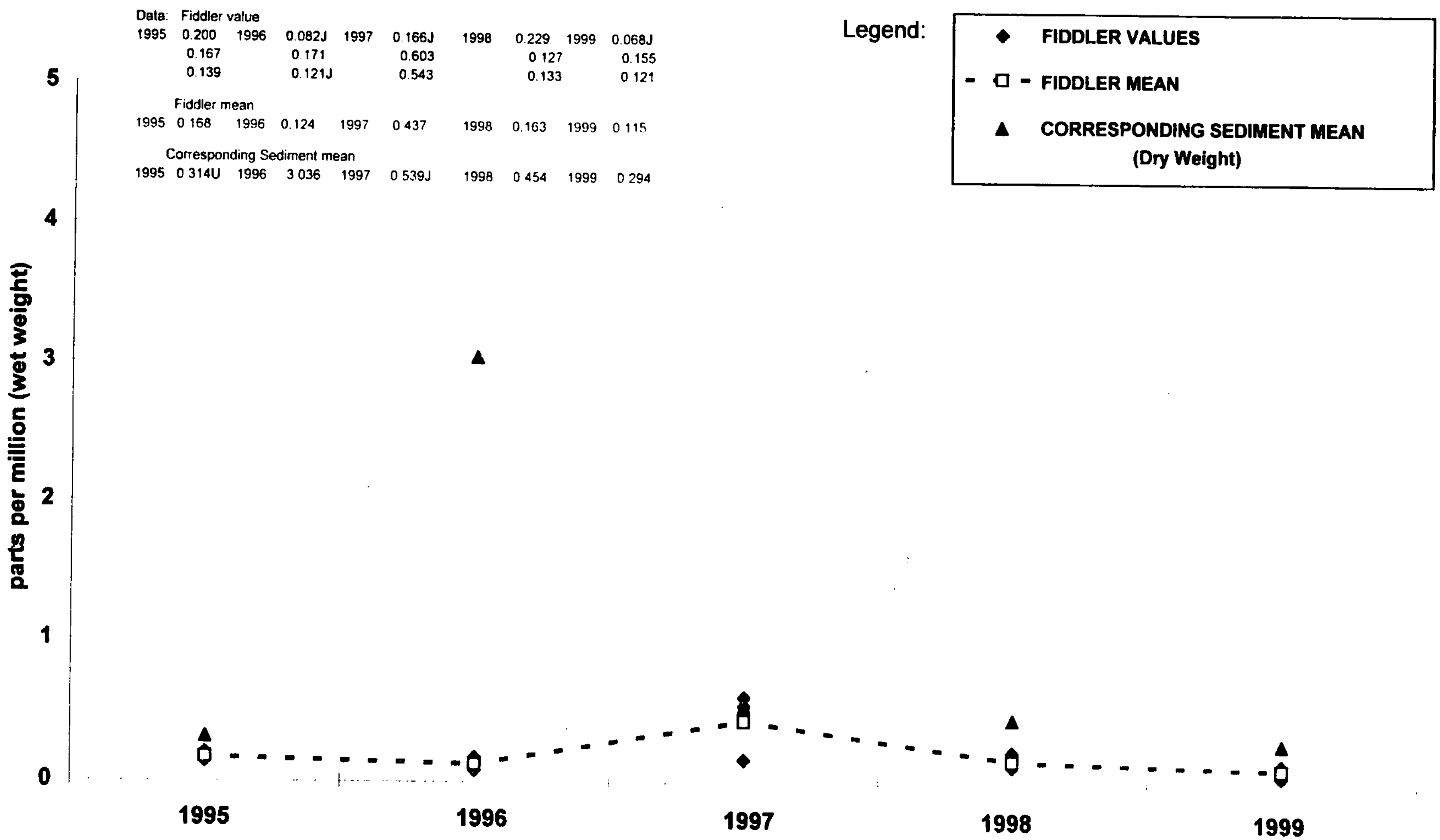


Figure 20. Five year PCB trend for fiddler crab tissue samples collected from Reference Zone 1 near Kin-Buc Landfill.



Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 21. Five year PCB trend for fiddler crab tissue samples collected from Reference Zone 2 near Kin-Buc Landfill.



Notes: 1) One-half detection limit was assumed for U-qualified data.

2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

5.0 MACOMA CLAM 28-DAY BIOACCUMULATION STUDY

The data generated from the fiddler crab tissue analysis were augmented with tissue data from a second burrowing invertebrate exposed to sediments collected from the study area under a controlled laboratory environment. The bent-nose macoma (*Macoma nasuta*) was selected as a test organism for a standard 28-day bioaccumulation test. *M. nasuta* is a small clam considered a "benchmark" species by the US EPA. They are deposit feeders that gather organic material with a pair of siphons along with sand and mud. *M. nasuta* grow to a length of about four inches. They are native to the Pacific coast but similar in feeding habit to related species of *Macoma* found along the Atlantic coast.

5.1 Materials and Methods

Sediment Collection

Sediment was collected on 2 through 4 August 1999 from nine pairs of transect locations (two per zone). Five samples were taken from remediated zones, and two each from unremediated and reference zones (Drawings 1 and 1.5) with a decontaminated shovel and/or Petite Ponar Grab. Samples were produced by collecting multiple grabs along the length of each transect (incorporating subtidal and intertidal habitats) until ten gallons of sediment were obtained. The samples were composited, homogenized, and transferred into lined 10-gallon coolers for transport (on ice) to the laboratory. Field measurements of water depth, water temperature, dissolved oxygen, pH, salinity, and conductivity were recorded with each sample. All water quality measurements were made at mid-depth.

Laboratory Analysis

Laboratory analysis for bioaccumulation was completed according to standard US EPA and U.S. Army Corps of Engineers (US ACOE) protocols (US EPA and US ACOE, 1991 and 1995). At the laboratory each of the sediment samples was partitioned into five aquariums to replicate the analyses. Sediment was layered to a depth of five centimeters on the bottom of each aquarium. A 10-liter volume of natural seawater, diluted to a salinity of 25 ppt, was added to each of forty-five test chambers plus five control chambers and allowed to settle overnight. Twenty-five macoma (five per chamber more than during the 1995 and 1996 analyses) were randomly introduced to each chamber and maintained at a temperature of 15 degrees Celsius. The additional macoma were seeded into each chamber to compensate for mortality (and consequent loss of tissue) incurred during the 1996 analysis. The water in each chamber was monitored for salinity, dissolved oxygen, and pH, and the macoma observed for mortality or abnormal behavior. Following the 28-day exposure period the macoma were removed from the test chambers, placed in clean seawater without any sediment, and allowed to purge the contents of their digestive tracts for twenty-four hours. Soft tissue was removed, placed into aluminum foil and frozen with dry ice prior to analysis for PCB and lipid content. The tissue samples from each chamber were pooled to produce a total of forty-five samples. In addition, five samples of tissue from the control chambers were analyzed as were three pretest samples. Analytical methodologies for PCBs and lipids were the same as those run for the crab tissues.

Data Analysis

Because this analytical approach evaluated the net transfer of the contaminant from the sediment to the tissue during a constant exposure period, the data were used to calculate location specific sediment/tissue ratios called bioaccumulation factors. The PCB data were normalized to the percent lipid concentrations in the tissues and reported both as micrograms per kilogram wet weight and micrograms per gram lipid. Statistics used to evaluate the data were the same as those run for the sediment and crab tissue data.

5.2 Results and Discussion

The results of the bio-accumulation study are presented as Table 4 using the same general format as for the sediment and fiddler crab analyses. Quality control results, Analysis Reports from Lancaster Labs and the Bioaccumulation Report from Envirosystems are presented in Appendix C. Also included in Appendix C are the Field Data Sheets. The field measurements of water quality made during the sediment collections are provided below. Water quality measurements were made at both transects within each zone:

Edmonds Creek Zones	Station	Water Temp. (C)	Dissolved Oxygen (mg/l)	pH (std. units)	Salinity (ppt)	Conductivity (µmhos/cm)
Remediated Zone 1	A10+50/	26.5	6.8	7.1	9.5	16,000
	12+00	26.5	6.7	7.1	9.5	15,950
Remediated Zone 2	A21+00/	29.0	5.7	7.1	12.5	21,500
	22+00	29.0	5.5	7.2	12.5	21,350
Unremediated Zone 2	ABIO-02/	29.0	5.4	7.4	13.5	25,000
	02A	29.0	5.5	7.3	13.5	25,000
Remediated Zone 3	A31+25/	28.5	5.0	7.1	16.0	27,000
	32+25	28.5	5.1	7.1	16.0	26,900
Remediated Zone 4	A42+25/	29.0	10.0	7.5	9.0	17,500
	46+50	29.0	6.9	7.4	9.1	17,400
Remediated Zone 5	A51+00/	28.5	7.5	7.4	8.0	14,000
	52+00	28.0	7.1	7.4	8.0	13,900
Unremediated Zone 1	ABIO-01/	27.5	8.4	6.9	7.5	14,000
	01A	27.5	7.5	7.0	7.4	14,050
Reference Creek Zones						
Reference Zone 1	ABIO-01/	28.0	6.5	7.2	9.5	16,500
	01A	28.0	6.1	7.2	9.5	16,500
Reference Zone 2	ABIO-02/	28.5	6.4	7.2	11.5	19,500
	02A	28.5	5.9	7.2	11.5	19,550

These data are typical of brackish water marsh systems subject to tidal fluctuations. Dissolved oxygen concentrations were consistently lower than they were during 1998, and salinity was much higher. An extended period of drought during the summer of 1999 appeared to have caused the atypical measurements.

5.2.1 Edmonds Creek Zones

Aroclors 1242, 1248, 1254, and 1260 were detected from the macoma tissues exposed to sediments collected from Edmonds Creek. In individual replicates Aroclors 1242, and 1248 were detected at concentrations ranging from 4 (U) to 1,330 μg/kg wet wt. Aroclors 1254 and 1260 were less concentrated; detected at concentrations ranging between 2 (U) and 155 μg/kg wet wt. Aroclor 1260 was only found at Remediated Zone 5 where trace concentrations were detected.

Within individual replicates total PCBs ranged between 52 and 2,505 μg/kg wet wt (0.052 and 2.505 ppm). The data for this controlled experiment differed from data collected from the fiddler crab analyses (an open system) as the samples with high total sediment PCB values were usually those where the greatest mean whole body PCB concentrations were found in corresponding tissue samples. Within particular zones, the mean concentrations for total PCBs ranged from 82 (Remediated Zone 1) to 2,003 (Unremediated Zone 1) μg/kg wet wt. Similar to the sediment analysis, relatively low accumulations, less than 0.1 ppm, were detected furthest upstream at Remediated Zones 1 and 2. Low means were also measured from the remaining remediated zones. Means for Remediated Zones 3, 4, and 5 ranged from 224 to 600 μg/kg wet wt. Relatively high values were observed from the two unremediated zones where means were 2,003 and 1,623 μg/kg wet wt at Remediated Zones 1 and 2, respectively.

In 1999 the mean fiddler crab body burdens within particular zones exceeded those from the macoma clams. This may simply be due to differential uptake or related to the longer exposure time for the fiddler crabs (the life span of the specimens) than that used for the macoma (twenty-eight days). However, assuming that twenty-eight days are sufficient for tissue concentrations in the macoma to reach equilibrium, it is possible that stress related to their introduction into foreign sediments limited feeding activity and, in turn, PCB uptake. These macoma were collected from their natural environment on the west coast (marine sands where salinity is near 33 ppt) and shipped on-ice to the laboratory for the analysis. There they were acclimated to a salinity of 25 ppt and introduced to the poor quality muck present throughout the Edmonds and Reference Creek channels. Although visual observations made during the experiment indicated that the macoma were behaving normally under experimental conditions, it would be difficult to ascertain whether their feeding rates resemble what they would be in the wild. Also, some mortality did occur during each year of the study and, although considered acceptable (see the Laboratory Report in Appendix C), this does suggest that the macoma do not thrive under experimental conditions.

Results from the macoma clam analysis produced tissue means ranging from < 0.1 to 2.7 ppm in particular study zones during the five year study period. By comparison, tissue means for fiddler crabs ranged between < 0.1 and 3.8 ppm. Thus, it appears that the crabs have been the better target organism to measure trends with.

Normalized values for individual replicates ranged from 10.4 to 902.5 μg/g lipid. Within particular zones, the mean concentrations ranged between 14.0 (Remediated Zone 1) and 468.1 (Unremediated Zone 1) μg/g lipid.

5.2.2 Reference Creek Zones

At Reference Creek zones Aroclors 1248, 1254, and 1260 accumulated to a sufficient degree to become detectable. Concentrations for Aroclors 1248 and 1254 ranged from 9 (J) to 40 μg/kg wet wt in individual replicates. Aroclor 1260 was less concentrated; detected at values ranging between 2 (U) and 11 (J) μg/kg wet wt. In individual replicates total PCBs ranged from 38 (J) to 112 μg/kg wet wt (0.038 and 0.112 ppm). Within zones mean whole body burdens were 0.093 μg/kg wet wt at Reference Zone 1 and 0.061 μg/kg wet wt at Reference Zone 2; lower than at Edmonds Creek in each case.

Normalized values for individual replicates ranged from 4.8 to 16.0 μg/g lipid. By zone normalized means were 12.7 μg/g lipid at Reference Zone 1 and 8.9 μg/g lipid at Reference Zone 2.

5.2.3 Concentration Factors

Here, concentration factors are reported for organic carbon normalized sediment/lipid normalized tissue ratios. These data are provided to evaluate the site specific uptake of total PCBs in the study zones. All results are reported on a dry weight basis for both the sediment and tissue values.

Zones	Transect Location	Sediment Concentration (μg/g OC dry wt)	Mean Tissue Concentration (μg/g lipid dry wt)	Concentration Factor
Remediated Zone 1	A10+50/12+00	166.3	188.0	0.9x
Remediated Zone 2	A21+00/22+00	116.7	137.3	0.8x
Unremediated Zone 2	UN-ABIO-02/02A	2,193.6	2,145.5	1.0x
Remediated Zone 3	A31+25/32+25	395.9	317.2	1.2x
Remediated Zone 4	A42+25/46+50	1,189.6	921.0	1.3x
Remediated Zone 5	A51+00/52+00	1,269.5	512.1	2.5x
Unremediated Zone 1	UN-ABIO-01/01A	726.0	4,589.2	0.2x
Reference Zone 1	RA-ABIO-01/01A	50.8	124.5	0.4x
Reference Zone 2	RA-ABIO-01/02A	63.9	89.0	0.7x

The normalized data indicated that sediment PCBs were concentrated to the same extent that the macoma samples were. Higher concentration factors were obtained from the samples from Edmonds Creek.

5.2.4 Five Year Trend

Edmonds Creek Zones

Encouraging results were also observed from the macoma clam analysis. Figures 22 through 28 show the PCB trends within each zone during the five-year monitoring period. Also given are the results for the corresponding sediment samples. All results are given as parts per million.

The mean whole body concentrations from the macoma clams remained stable or trended downward during the course of the study at six of seven Edmonds Creek zones in a similar fashion to the fiddler crab whole body concentrations (note that the 1996 macoma results were positively biased due to mortality incurred during the exposure period that limited the amount of tissue available for analysis). Although the tissue means were positively correlated with sediment samples containing the highest PCB concentrations, the macoma never accumulated PCBs to levels that, on an absolute scale, approached those of the most concentrated sediment samples. Restated, the macoma concentrations seldom exceeded values greater than 2 ppm regardless of the corresponding sediment concentrations; as high as 15 ppm. The only instances where tissue means were similar to corresponding sediment concentrations were when sediment concentrations were low. Examples of this are shown for the 1995 results at each zone where results for both matrices were similar. Subsequent results produced a much wider gap between the respective matrices. Although the results are sufficient to conclude that residual PCBs in the Edmonds Creek sediments will bio-accumulate, the bioaccumulative capacity of the target organism appeared limited (see Section 5.2.1) making temporal trends more difficult to see. More discernable trends were observed from the fiddler crab analysis where tissue samples collected from the marsh per se provided a more direct measurement. Not withstanding, results for both target organisms showed modest reductions in body burdens during the study period.

Remediated Zones 1 and 2

At both zones upstream from OU2 tissue means were low each year and trended slightly downward. Annual means at Remediated Zone 1 were 0.130 (1995), 0.679 (U) (1996), 0.161 (1997), 0.074 (1998), and 0.092 (1999) ppm (Figure 22). Tissue means were close to corresponding sediment values in 1995 and then tended to diverge there after as redistribution of residual of PCBs produced slight increases in sediment values.

Nearly identical means of 0.180 (1995), 0.854 (U) (1996), 0.264 (1997), 0.138 (1998), and 0.082 (1999) ppm were calculated at Remediated Zone 2 (Figure 23). Tissue means were similar to corresponding sediment values only during 1995. However, similar trends were observed for both matrices.

Unremediated Zone 2

Adjacent to OU2 tissue means were slightly higher than at the two upstream remediated zones and essentially remained unchanged during the monitoring period. From 1995 to 1998 means trended downward and were 1.646 (1995), 1.496 (1996), 1.408 (1997), and 0.796 (1998) ppm (Figure 24). In 1999 a tissue mean of 1.623 was nearly identical to the 1995 mean. Tissue means were near corresponding sediment values in 1995 and 1996. During 1997 through 1999 sediment values increased.

Remediated Zones 3 and 4

Downstream from OU2 mean macoma body burdens continued to show a gradual decline over the course of the monitoring period. At Remediated Zone 3 annual tissue means were 0.362 (1995), 1.002 (1996), 0.323 (1997), 0.188 (1998), and 0.224 ppm (Figure 25). Both the means and the temporal trend of decreasing tissue burdens were similar to those observed at Remediated Zones 1 and 2. Tissue means were similar to the corresponding sediment means during 1995 and 1996 but considerably less thereafter.

At Remediated Zone 4 tissue means generally decreased during the monitoring period. A 1995 mean of 1.456 ppm was followed by means of 0.916 (1996), 0.754 (1997), 0.536 (1998), and 0.600 (1999) ppm (Figure 26). The tissue mean was similar to the corresponding sediment value only in 1995.

Remediated Zone 5 and Unremediated Zone 1

The data from the two most downstream zones indicated the degree of uptake to be either unchanged or slightly increased during the five-year study period. At Remediated Zone 5 annual tissue means increased between 1995 and 1996 and then declined thereafter. Mean values were 0.311 (1995), 1.908 (1996), 0.814 (1997), 0.684 (1998), and 0.413 ppm (Figure 27). Tissue means were close to corresponding sediment values in 1995 but rose only slightly thereafter.

The greatest amount of bioaccumulation was observed at the mouth of Edmonds Creek at Unremediated Zone 1. There tissue means were of 1.303 (1995), 2.746 (1996), 2.446 (1997), 0.850 (1998), and 2.003 (1999) ppm (Figure 28); a slight upward trend. The higher tissue accumulations corresponded to higher sediment concentrations, particularly those from 1996 to 1998 that ranged between 13 and 14 ppm. However, actual tissue concentrations were close to the corresponding sediment concentrations only during 1995 and 1999 when lower sediment values were recorded.

Reference Creek Zones

The trends in macoma whole body burdens within the Reference Creek zones are shown in Figures 29 and 30. These means were lower than those from Edmonds Creek and remained consistent during the study period at both zones. Means from 1995 to 1999 were 0.098 (U), 0.795 (U), 0.031, 0.051, and 0.093 ppm, respectively, at Reference Zone 1, and 0.098 (U), 1.512 (U), 0.021 (J), 0.047, and 0.061 ppm, respectively, at Reference Zone 2.

Table 4. Kin-Buc Project - PCB concentrations in *Macoma nasuta* tissue samples from 28-day Sediment Bioaccumulation Bioassay during 1999 (year 5).

Sample ID Number	Replicate Number	PCB Tissue Concentration (μg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (μg/kg wet wt)	Normalized sum of Aroclors (μg/g lipid)	Percent Lipid
Edmonds Creek Remediated Zone 1:											
A10+50/12+00	1	2 U	4 U	5 U	4 U	87	2 U	2 U	106	-	-
	2	2 U	4 U	5 U	4 U	51	2 U	2 U	70	-	-
	3	5 U	12 U	14 U	10 U	64	23 J	5 U	133	-	-
	4	2 U	4 U	5 U	4 U	26	9 J	2 U	52	10.4	0.5
	5	2 U	4 U	5 U	4 U	29	11 J	2 U	97	24.2	0.4
								Mean	92	17.3	
								Std. error of the mean	14	6.9	
								Coefficient of Variation	34.3%	56.4%	
Edwards Creek Remediated Zone 2:											
A21+00/22+00	1	2 U	4 U	5 U	4 U	43	16 J	2 U	76	12.7	0.6
	2	2 U	4 U	5 U	4 U	63	18	2 U	98	16.3	0.6
	3	2 U	4 U	5 U	4 U	42	13 J	2 U	72	14.4	0.5
	4	2 U	4 U	5 U	4 U	33	10 J	2 U	60	12.0	0.5
	5	2 U	4 U	5 U	4 U	63	22	2 U	102	14.6	0.7
								Mean	82	14.0	
								Std. error of the mean	8	0.8	
								Coefficient of Variation	21.8%	12.1%	

Table 4. continued.

Sample ID Number	Replicate Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Unremediated Zone 2:											
UN-ABIO-02/02A	1	25 U	60 U	70 U	530	660	25 U	25 U	1,395	232.5	0.6
	2	25 U	60 U	70 U	610	770	25 U	25 U	1,585	226.4	0.7
	3	25 U	60 U	70 U	690	770	25 U	25 U	1,665	208.1	0.8
	4	25 U	60 U	70 U	640	720	25 U	25 U	1,565	195.6	0.8
	5	25 U	60 U	70 U	840	860	25 U	25 U	1,905	317.5	0.6
								Mean	1,623	236.0	
								Std. error of the mean	83	21.4	
								Coefficient of Variation	11.4%	20.3%	
Edmonds Creek Remediated Zone 3:											
A31+25/32+25	1	2 U	4 U	5 U	5 U	202	30	2 U	250	31.2	0.8
	2	2 U	4 U	5 U	4 U	145	22	2 U	184	26.3	0.7
	3	2 U	4 U	5 U	4 U	140	23	2 U	180	22.5	0.8
	4	2 U	4 U	5 U	4 U	148	23	2 U	188	31.3	0.6
	5	2 U	4 U	5 U	4 U	274	29	2 U	320	45.7	0.7
								Mean	224	31.4	
								Std. error of the mean	27	3.9	
								Coefficient of Variation	27.1%	28.0%	

Table 4. continued.

Sample ID Number	Replicate Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Remediated Zone 4:											
A42+25/46+50	1	16 U	39 U	46 U	35 U	380	16 U	16 U	548	78.3	0.7
	2	16 U	39 U	46 U	35 U	570	16 U	16 U	738	105.4	0.7
	3	16 U	39 U	46 U	35 U	390	16 U	16 U	558	111.6	0.5
	4	16 U	39 U	46 U	35 U	490	16 U	16 U	658	82.2	0.8
	5	16 U	39 U	46 U	35 U	330	16 U	16 U	498	83.0	0.6
								Mean	600	92.1	
								Std. error of the mean	43	6.8	
								Coefficient of Variation	16.1%	16.5%	
Edmonds Creek Remediated Zone 5:											
A51+00/52+00	1	2 U	4 U	5 U	4 U	198	25	2 U	240	26.7	0.9
	2	2 U	4 U	5 U	4 U	176	26	2 U	219	36.5	0.6
	3	2 U	6 U	7 U	6 U	392	178	11 J	602	-	-
	4	2 U	6 U	7 U	6 U	319	140	8 J	488	69.7	0.7
	5	2 U	6 U	7 U	6 U	333	155	10 J	519	86.5	0.6
								Mean	413	54.8	
								Std. error of the mean	77.5	14.0	
								Coefficient of Variation	41.9%	51.1%	

Table 4. continued.

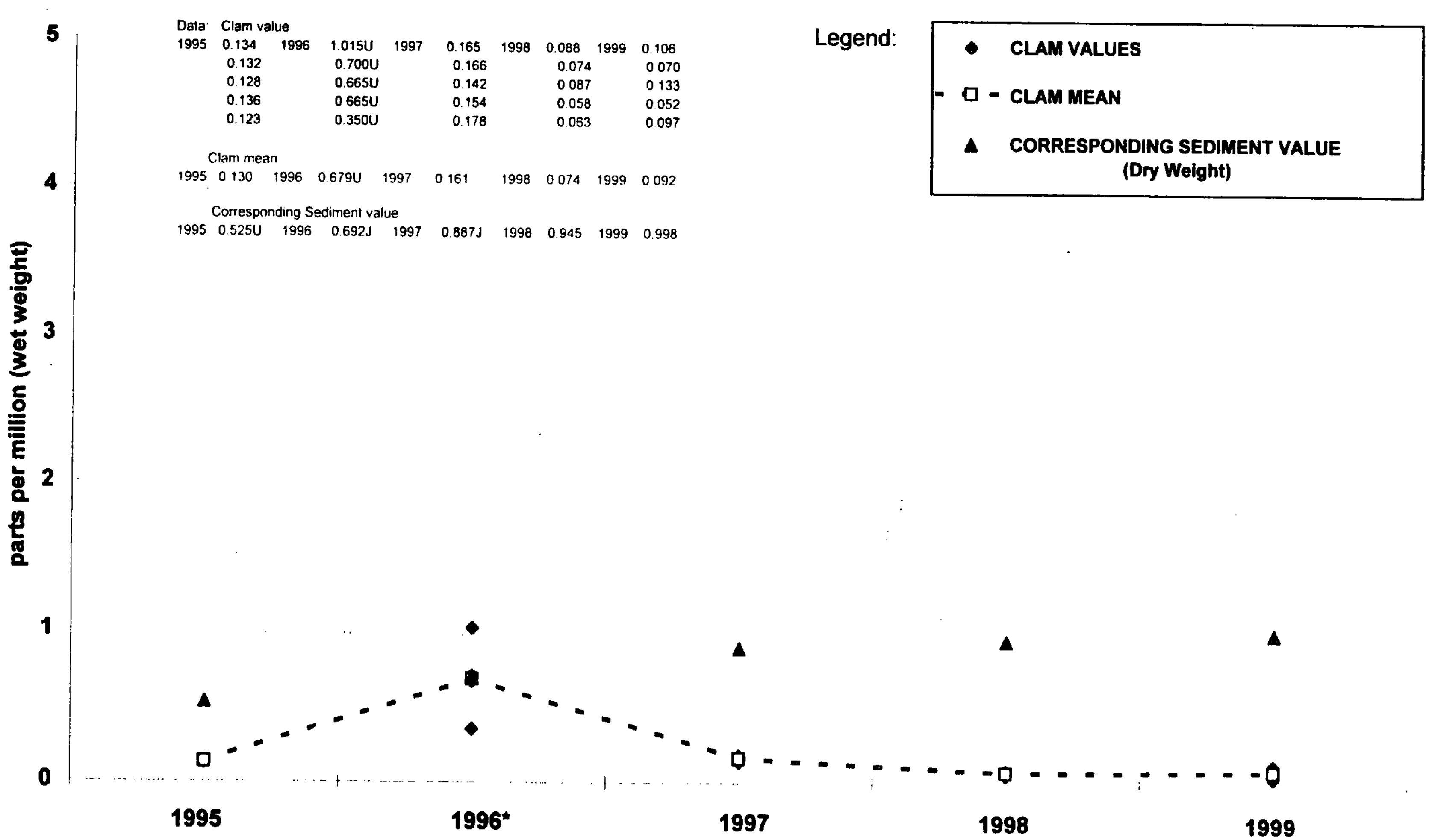
Sample ID Number	Replicate Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Unremediated Zone 1:											
UN-ABIO-01/01A	1	25 U	60 U	70 U	1,020	700	25 U	25 U	1,925	275.0	0.7
	2	25 U	60 U	70 U	1,330	970	25 U	25 U	2,505	501.0	0.5
	3	25 U	60 U	70 U	1,120	810	25 U	25 U	2,135	427.0	0.5
	4	25 U	60 U	70 U	910	690	25 U	25 U	1,805	902.5	0.2
	5	25 U	60 U	70 U	830	610	25 U	25 U	1,645	235.0	0.7
								Mean	2,003	468.1	
								Std. error of the mean	149	119.0	
								Coefficient of Variation	16.6%	56.8%	
Reference Creek Zone 1:											
RA-ABIO-01/01A	1	2 U	6 U	7 U	6 U	37	23 J	2 U	83	-	-
	2	2 U	6 U	7 U	6 U	36	24 J	2 U	83	-	-
	3	2 U	6 U	7 U	6 U	30	29	9 J	89	8.1	1.1
	4	2 U	6 U	7 U	6 U	34	32	10 J	97	13.9	0.7
	5	2 U	6 U	7 U	6 U	40	40	11 J	112	16.0	0.7
								Mean	93	12.7	
								Std. error of the mean	5	2.4	
								Coefficient of Variation	13.1%	32.2%	

Table 4. continued.

Sample ID Number	Replicate Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Reference Creek Zone 2:											
RA-ABIO-02/02A	1	2 U	6 U	7 U	6 U	14 J	22 J	2 U	59 J	9.8	0.6
	2	5 U	12 U	14 U	10 U	12 U	21 J	5 U	79 J	11.3	0.7
	3	2 U	6 U	7 U	6 U	6 U	9 J	2 U	38 J	4.8	0.8
	4	5 U	12 U	14 U	10 U	12 U	12 J	5 U	70 J	8.8	0.8
	5	2 U	6 U	7 U	6 U	19 J	16 J	2 U	58 J	9.7	0.6
								Mean	61	8.9	
								Std. error of the mean	7	1.1	
								Coefficient of Variation	25.2%	27.5%	

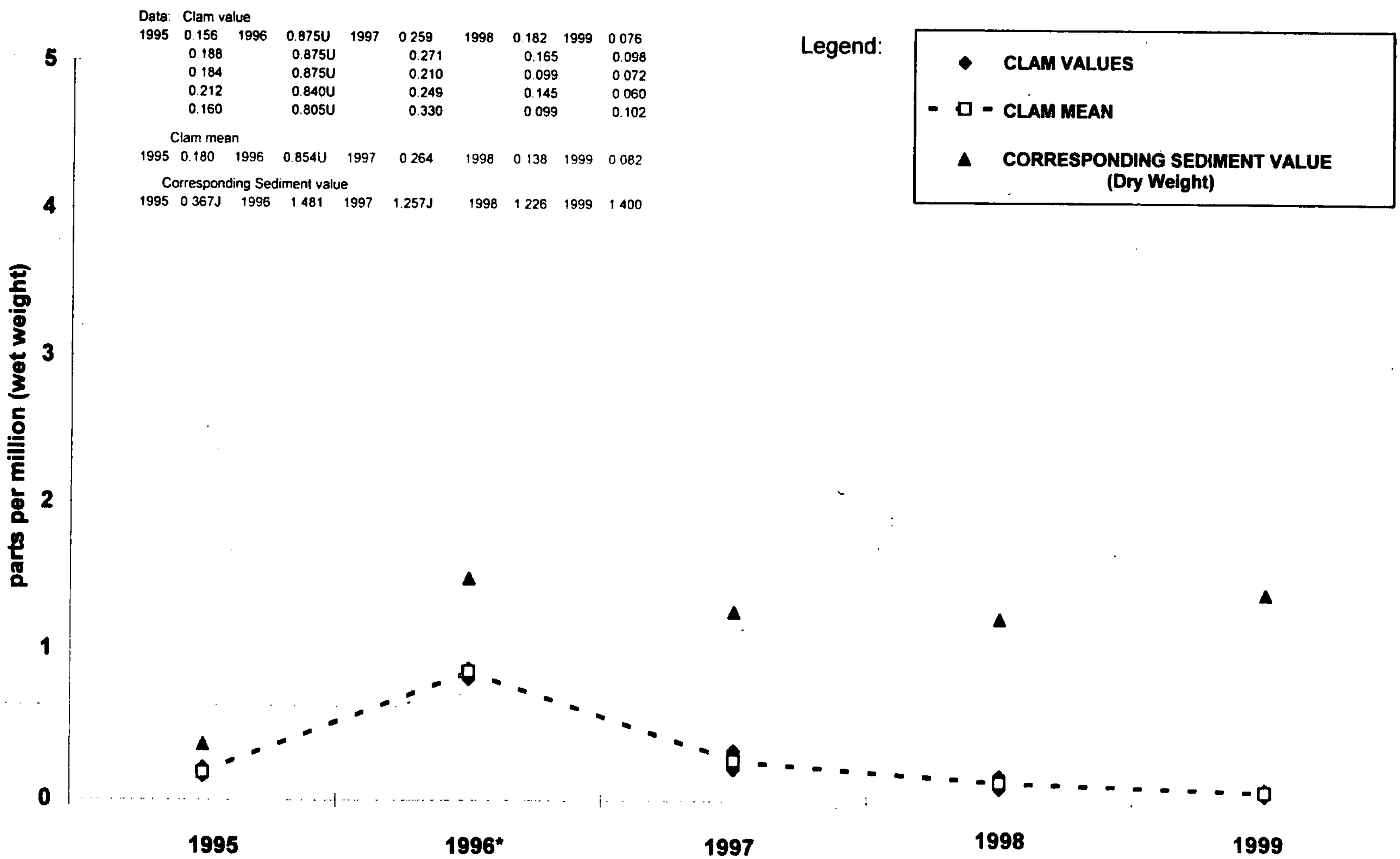
Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Figure 22. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Remediated Zone 1 near Kin-Buc Landfill.



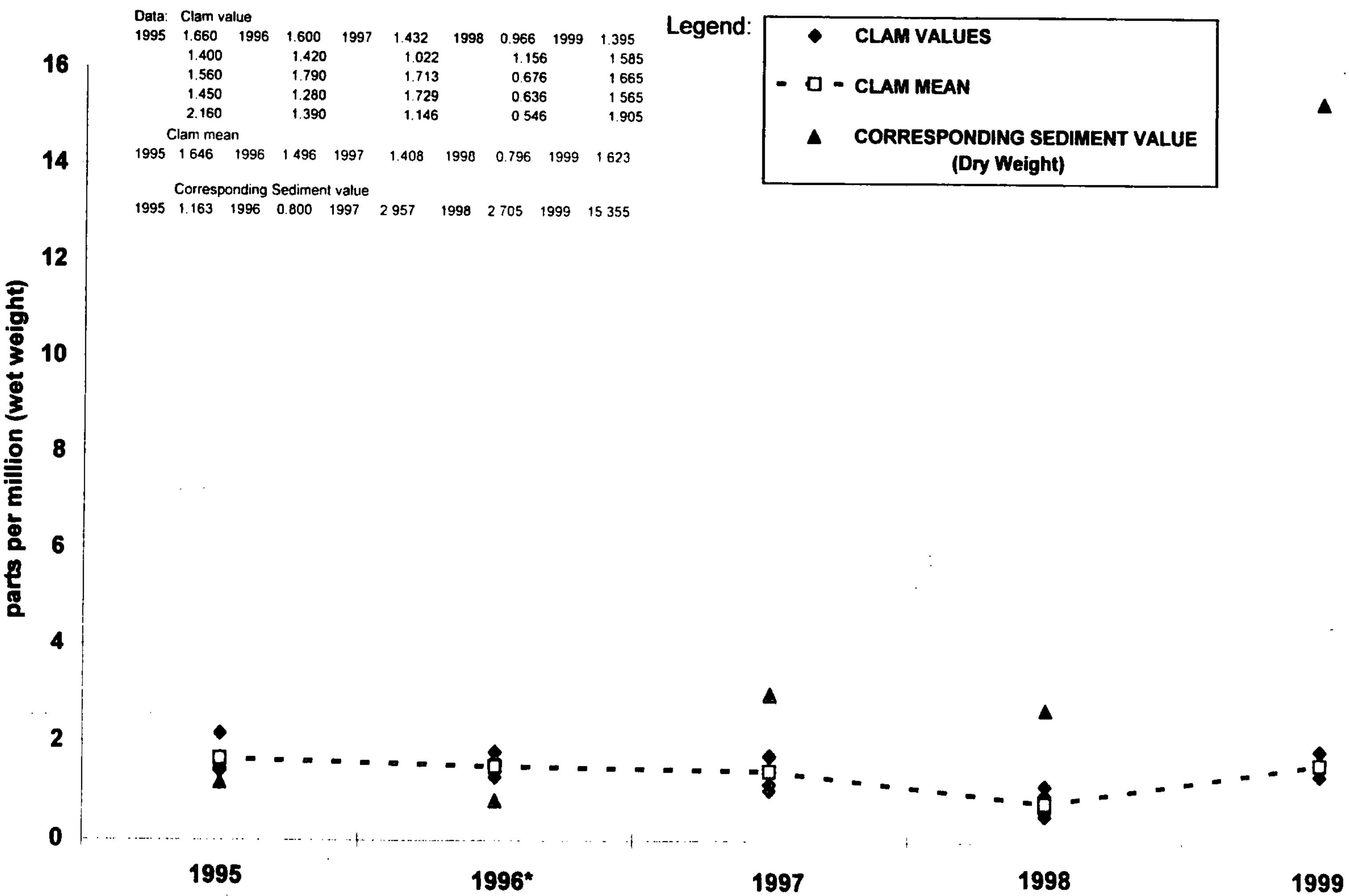
Note: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit of quantitation are J-qualified.
3) *1996 macoma means were positively biased due to elevated detection limits.

Figure 23. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Remediated Zone 2 near Kin-Buc Landfill.



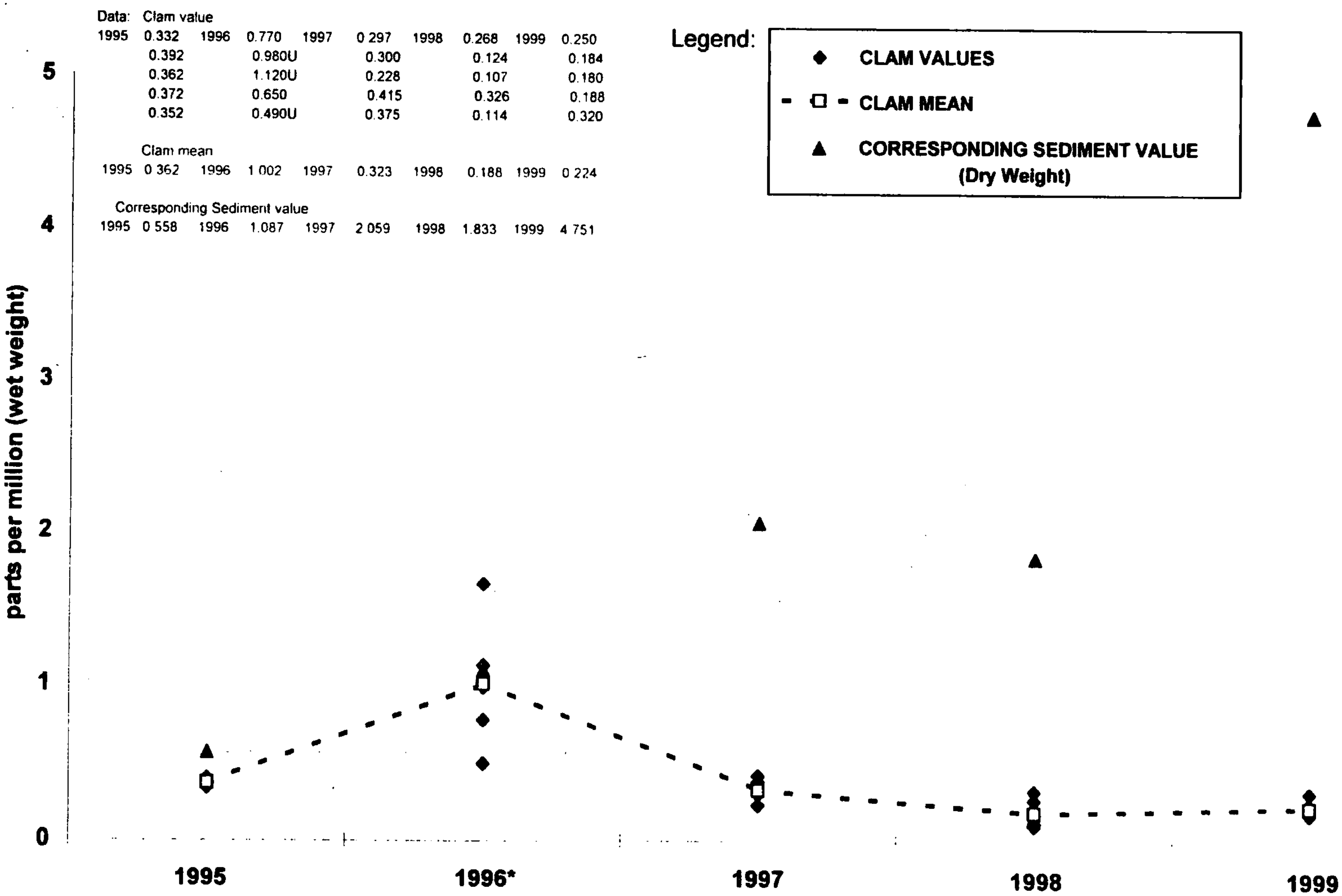
Note: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit of quantitation are J-qualified.
3) *1996 macoma means were positively biased due to elevated detection limits.

Figure 24. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Unremediated Zone 2 near Kin-Buc Landfill.



Note: 1)*1996 macoma means were positively biased due to elevated detection limits.

Figure 25. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Remediated Zone 3 near Kin-Buc Landfill.



Data: Clam value

1995		1996		1997		1998		1999	
	0.332		0.770		0 297		0.268		0.250
	0.392		0.980U		0.300		0.124		0.184
	0.362		1.120U		0.228		0.107		0.180
	0.372		0.650		0.415		0.326		0.188
	0.352		0.490U		0.375		0.114		0.320

Clam mean

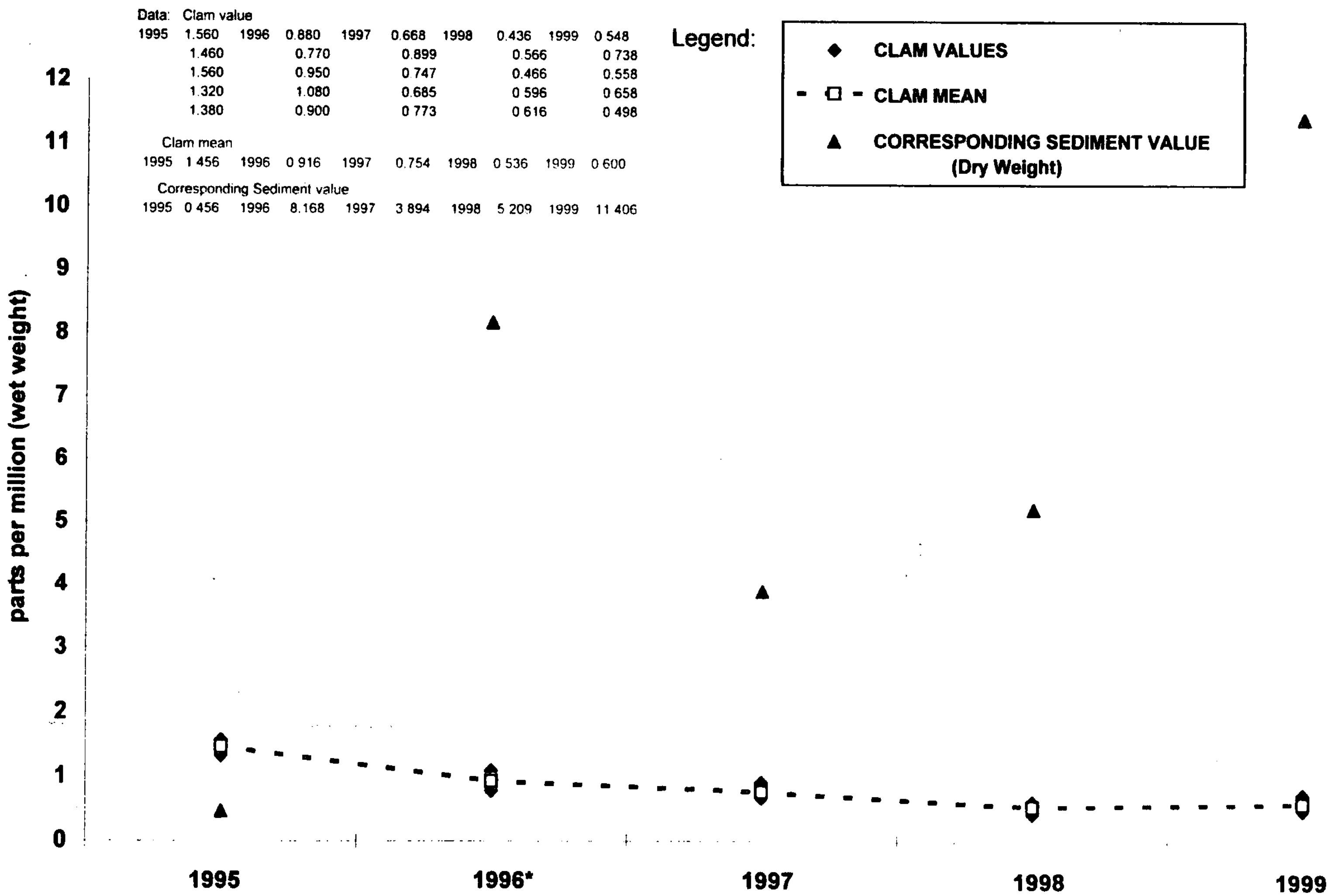
1995	0 362	1996	1 002	1997	0.323	1998	0.188	1999	0 224

Corresponding Sediment value

1995	0 558	1996	1.087	1997	2 059	1998	1.833	1999	4 751

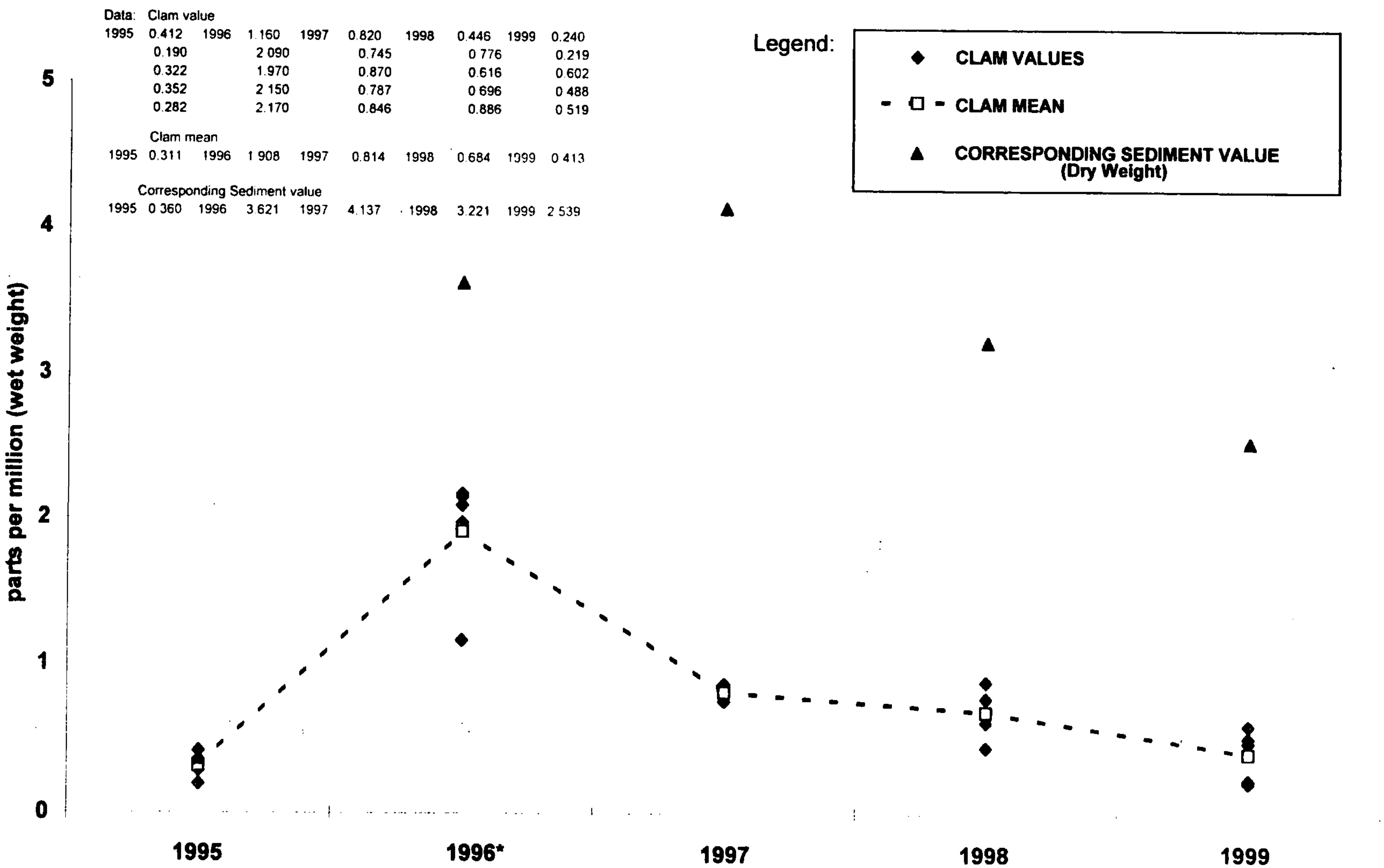
Note: 1) One-half detection limit was assumed for U-qualified data.
2) *1996 macoma means were positively biased due to elevated detection limits.

Figure 26. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Remediated Zone 4 near Kin-Buc Landfill.



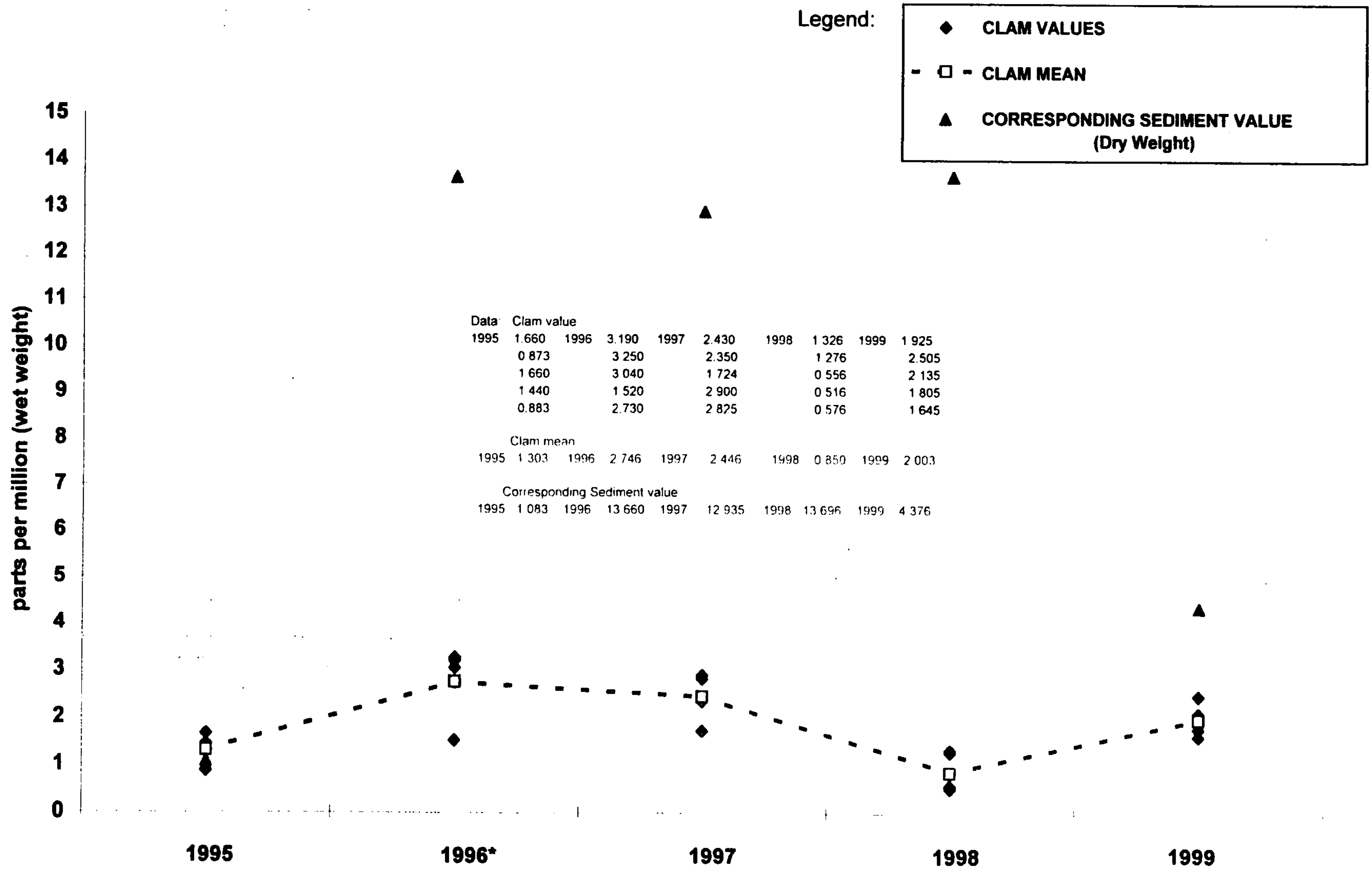
Note: 1) *1996 macoma means were positively biased due to elevated detection limits.

Figure 27. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Remediated Zone 5 near Kin-Buc Landfill.



Note: 1) *1996 macoma means were positively biased due to elevated detection limits.

Figure 28. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Unremediated Zone 1 near Kin-Buc Landfill.



Data: Clam value

1995	1.660	1996	3.190	1997	2.430	1998	1 326	1999	1 925
	0 873		3 250		2.350		1 276		2.505
	1 660		3 040		1 724		0 556		2 135
	1 440		1 520		2 900		0 516		1 805
	0.883		2.730		2 825		0 576		1 645

Clam mean

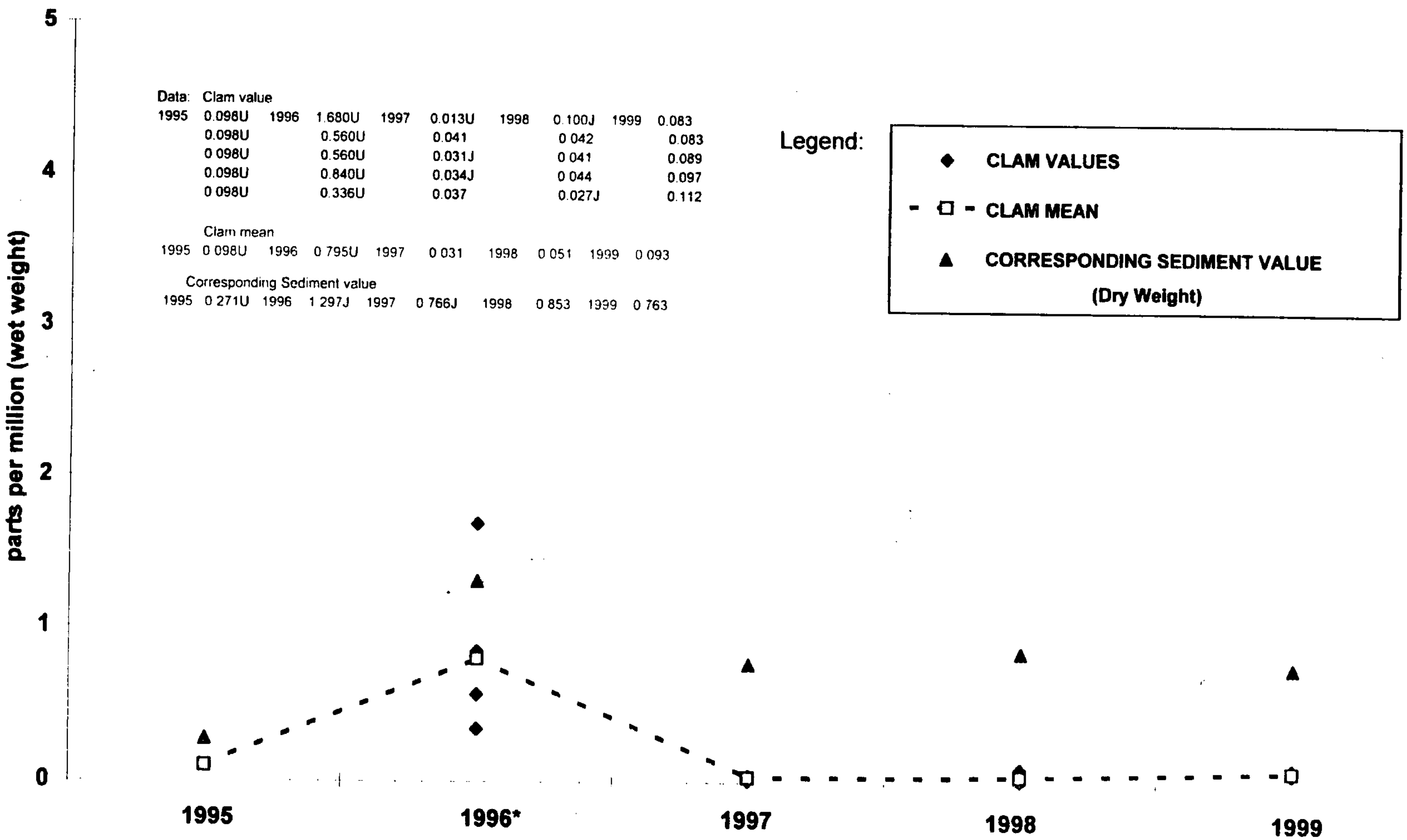
1995	1 303	1996	2 746	1997	2 446	1998	0 850	1999	2 003

Corresponding Sediment value

1995	1 083	1996	13 660	1997	12 935	1998	13 696	1999	4 376

Note: 1) *1996 macoma means were positively biased due to elevated detection limits.

Figure 29. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Reference Zone 1 near Kin-Buc Landfill.



Data: Clam value

1995	0.098U	1996	1.680U	1997	0.013U	1998	0.100J	1999	0.083
	0.098U		0.560U		0.041		0 042		0.083
	0 098U		0.560U		0.031J		0 041		0.089
	0.098U		0.840U		0.034J		0 044		0.097
	0 098U		0.336U		0.037		0.027J		0.112

Clam mean

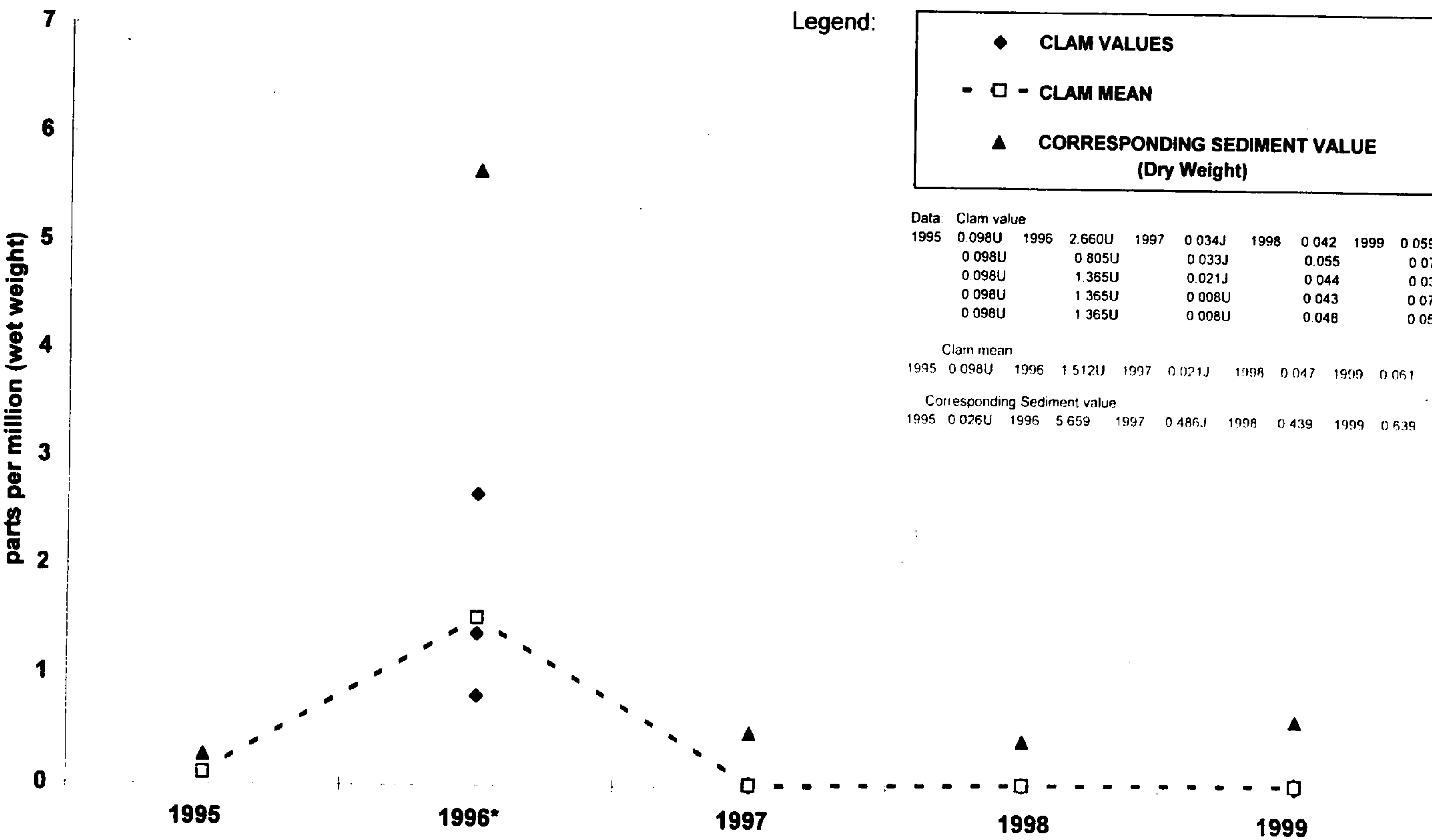
1995	0 098U	1996	0 795U	1997	0 031	1998	0 051	1999	0 093

Corresponding Sediment value

1995	0 271U	1996	1 297J	1997	0 766J	1998	0 853	1999	0 763

Note: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit of quantitation are J-qualified.
3) *1996 macoma means were positively biased due to elevated detection limits.

Figure 30. Five year PCB trend for macoma clam tissue samples exposed to sediments collected at Reference Zone 2 near Kin-Buc Landfill.



Data: Clam value

1995	0.098U	1996	2.660U	1997	0.034J	1998	0.042	1999	0.059J
	0.098U		0.805U		0.033J		0.055		0.079J
	0.098U		1.365U		0.021J		0.044		0.038J
	0.098U		1.365U		0.008U		0.043		0.070J
	0.098U		1.365U		0.008U		0.048		0.058J

Clam mean

1995	0.098U	1996	1.512U	1997	0.021J	1998	0.047	1999	0.061

Corresponding Sediment value

1995	0.026U	1996	5.659	1997	0.486J	1998	0.439	1999	0.639

Note: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit of quantitation are J-qualified.
3) *1996 macoma means were positively biased due to elevated detection limits.

6.0 MUMMICHOG TISSUE ANALYSIS

Seine collections were made according to methods described by US EPA in, "Fish Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters" (EPA/600/R-92/111), to collect tissue for PCB analyses from a third target species.

The collection strategy for the fish tissue analysis differed somewhat from that of the invertebrates because fish are considerably more mobile than fiddler crabs and not as good an indicator of local (within zone) differences in PCB uptake. The mummichog (*Fundulus heteroclitus*) is a small fish that is found in the water column. It was selected as a target organism because, although more mobile than fiddler crabs, they exhibit a limited home range and can indicate differences in PCB concentrations at a broader (stream wide) scale.

6.1 Materials and Methods

Collection

Mummichogs were collected from 31 August through 2 September and on 9 September 1999 from eight zones within both Edmonds Creek and Reference Creek (Drawings 2 and 2.5).

From Edmonds Creek, samples were taken from five remediated and three unremediated zones. Individual fish were captured with an 8-foot block seine (similar to Figure 31), rinsed with distilled water, placed in aluminum foil and zip-loc bags, and frozen prior to analysis. Two samples were collected at each zone; one consisting of juveniles and a second, of mature individuals. A total of sixteen samples, (plus two field duplicates) was submitted for analysis.

This year mummichogs were conspicuously absent from Reference Creek. An initial capture effort was made with a seine, during most of the day on 2 September, that produced enough mummichogs for one sample within Zone 1. We revisited the site on 9 September when, in addition to the seine, baited minnow traps were used in an attempt to augment the seining effort. However, the mummichogs had not returned and only enough specimens were captured to produce one additional sample, from Zone 8.

The lack of mummichogs in Reference Creek appeared to be related to a rather odd dynamic that occurred prior to the sample effort as a result of hurricanes Dennis and Emily. As a result of rainfall produced by these hurricanes, runoff of fresh water to the Raritan Basin had elevated river flow and produced atypically low salinity (measured at 2.5 ppt on 9 September) within the river channel. Conversely, runoff within the more localized basin that drains Reference Creek remained closer to normal and salinity was higher (measured between 5 and 7 ppt on 9 September). Evidently, tidal mixing with water from the Raritan was insufficient to decrease salinity in Reference Creek to the extent that occurred in the main channel. It appeared that the mummichogs exhibited a differential preference for the lower salinity and migrated out of the study area. Interestingly, schools of Atlantic menhaden, that prefer higher salinity, were observed moving into Reference Creek at the same time. We believe a similar dynamic occurred in Edmonds Creek but at a slightly later (one-week) time. Thus, mummichogs were available there when the capture effort began.

All mummichogs were measured and lengths recorded. Fish caught from all other species were also identified and measured. Physical attributes of each sampling zone were noted on field sheets including shading, water depth, color, current (tide stage), the composition of the substrate, and the dominant types of vegetation. Any structural features that would provide living space or refuge for the fish community such as snags, floating driftwood, and aquatic vegetation were also noted. Measurements of water depth, water clarity; and mid-depth measurements of water temperature, dissolved oxygen, pH, salinity, and conductivity accompanied each collection.

Analysis

Tissue samples were analyzed for PCBs and percent lipids using the same procedures as for the fiddler crab and macoma analyses. The PCB results were normalized to the lipid content of the tissues and reported both as micrograms per kilogram wet weight and micrograms per gram lipid. Descriptive statistics used to evaluate the data were range, mean, standard error of the mean, and coefficient of variation.

6.2 Results and Discussion

As expected, there was little difference in the PCB results between individual zones at Edmonds Creek. In the Reference Area, average PCB concentrations in the fish tissues were lower. PCB data are given as Tables 5a and 5b. Quality control results, Analysis Reports from the PCB tests, Seine Data Sheets, and Aquatic Habitat Evaluation Forms are provided in Appendix D.

A comparison between samples consisting of "adult" fish versus samples containing only "juvenile" fish is provided here. Results are given parts per million wet weight:

Edmonds Creek Zones	"Juvenile" Samples	"Adult" Samples
Remediated Zone 1	1.958	3.149
Remediated Zone 2	1.839	2.751
Unremediated Zone 3	1.016	1.943
Unremediated Zone 2	1.172	1.884
Remediated Zone 3	1.380	1.963
Remediated Zone 4	0.672	1.713
Remediated Zone 5	1.363	1.513
Unremediated Zone 1	2.868	2.580
Reference Creek Zones		
Reference Zone 1	–	0.434
Reference Zone 8	–	0.228

In Edmonds Creek greater concentrations were observed for the adult specimens in six of eight zones. This suggested that the older members of the community were accumulating PCBs to a greater extent. Both samples collected from Reference Creek consisted of adult specimens.

6.2.1 Edmonds Creek Zones

Habitat and Water Quality

Edmonds Creek is a muddy brackish water stream with a meandering channel. Meanders formed coves at several locations, and current was slow and tidal. The stream bottom was muddy throughout the study area. Streamside vegetation consisted of a dense growth of *Phragmites* that provided shading for part of the water surface and habitat refuge for the fish community during high tide when inundated by water. Saltmarsh grass (*Spartina*) was observed in patches along the water edge. The canopy was mostly open. Instream vegetation was scarce and consisted mostly of *Lemna* (floating pond-weed), but some cover in the form of drifting timber and woody debris was present. Meanders also provided some habitat structure.

Field measurements of water quality (all made during low tide when mummichogs are easy to catch) were as follows:

Edmonds Creek Zones	Water Clarity (ft)	Water Temp. (C)	Dissolved Oxygen (mg/l)	pH (std. units)	Salinity (ppt)	Conductivity (µmhos/cm)
Remediated Zone 1	0.9	23.0	4.6	7.1	8.0	12,100
Remediated Zone 2	0.8	23.0	4.5	7.1	8.0	12,100
Unremediated Zone 3 (Trib)	bot	23.5	4.8	7.0	8.0	12,700
Unremediated Zone 2	0.9	23.5	4.8	7.1	8.5	12,300
Remediated Zone 3	0.8	23.0	4.8	7.1	9.0	12,500
Remediated Zone 4	1.2	19.0	5.2	7.0	5.5	7,900
Remediated Zone 5	1.1	22.0	5.1	6.8	5.5	8,400
Unremediated Zone 1	1.2	22.0	4.7	6.8	5.5	8,800

These results show low tide conditions in Edmonds Creek. Water temperatures indicated a warmwater stream with low dissolved oxygen and neutral to slightly acidic pH. Salinity measurements confirmed the brackish nature of the system, but were consistently higher than salinities measured during 1998.

Polychlorinated Biphenyls

As expected, whole body burdens, expressed as total PCB concentrations, tended to be consistent among samples collected from different zones. Three Aroclors were detected. Aroclors 1248 and 1254 were the most prevalent ranging from 193 to 2,310 µg/kg wet wt in individual samples. Less prevalent was Aroclor 1260, measured at concentrations between 54 and 270 µg/kg wet wt in individual samples.

Total PCB results for individual samples collected from Edmonds Creek ranged between 672 and 3,149 µg/kg wet wt (0.672 and 3.149 ppm). The sample means within particular zones ranged from 1,192 (Remediated Zone 4) to 2,724 (Unremediated Zone 1) µg/kg wet wt. Most of the sample means were between 1 and 2 ppm.

Following lipid normalization the total PCB concentrations assumed values ranging between 42.0 and 179.2 µg/g lipid in individual samples. By zone, sample means ranged from 64.2 to 165.5 µg/g lipid.

6.2.2 Reference Creek Zones

Habitat and Water Quality

Habitat and water quality characteristics within Reference Creek were nearly identical to those in Edmonds Creek except that the channel was straighter and slightly narrower. The water was muddy, and current slow and tidal. The stream bottom consisted almost entirely of soft mud with some isolated sandy areas. Streamside vegetation consisted primarily of *Phragmites* that partially shaded the water surface. Eurasian milfoil was seen growing from the stream bottom in a few locations but provided limited cover for the fish community. Woody debris and driftwood provided some additional cover. Abundant cover was provided by the phragmites growing along the shorelines, when inundated by high tide. Water quality measurements (again taken at low tide) were as shown below:

Reference Creek Zones	Water Clarity (ft)	Water Temp. (C)	Dissolved Oxygen (mg/l)	pH (std. units)	Salinity (ppt)	Conductivity (µmhos/cm)
Reference Zone 1	0.9	22.0	4.9	6.8	7.0	11,500
Reference Zone 2	1.2	24.0	5.5	6.7	5.0	8,000
Reference Zone 3	1.3	24.0	5.2	6.7	5.0	8,000
Reference Zone 4	1.0	24.5	4.6	6.7	5.0	8,000
Reference Zone 5	1.2	24.5	5.1	6.7	5.0	8,050
Reference Zone 6	1.7	24.0	5.8	6.8	5.0	8,000
Reference Zone 7	1.7	24.0	5.8	6.8	5.0	8,000
Reference Zone 8	1.8	24.0	5.7	6.8	5.0	8,000

These results showed similar low tide conditions to those measured at Edmonds Creek. Salinity measurements were higher in 1999 than they were in 1998.

Polychlorinated Biphenyls

Aroclor concentrations were lower in the fish at Reference Creek. Aroclors 1248, 1254, and 1260 were detected. Aroclor 1254 was most prevalent, ranging from 75 to 180 µg/kg wet wt, in the two samples. Less concentrated Aroclors, 1248 and 1260, ranged from 56 to 114 µg/kg wet wt.

Total PCB concentrations ranged from 228 to 434 µg/kg wet wt (0.228 and 0.434 ppm) in the two samples. The results were consistent with results from the other analyses (sediment, fiddler crab, and macoma) in that the reference data showed less contamination than did data from Edmonds Creek.

Lipid normalized concentrations were 6.6 and 21.7 µg/g lipid.

6.2.3 Five Year Trend

Edmonds Creek Zones

Trends in the PCB results observed from the mummichog tissues collected at Edmonds Creek are given as Figures 32 through 39. All results are given in parts per million. Relatively low tissue means, between

0.5 and 0.8 ppm, were observed in 1995. From 1996 to 1999 means did not produce clear trends but tended to fluctuate between 1 and 2.5 ppm. Most annual means remained below 2 ppm.

Remediated Zones 1 through 2 and Unremediated Zone 3

These zones are located upstream from OU2. At Remediated Zone 1, mean values from 1995 to 1999 were 0.590, 0.885, 1.784, 1.182, and 2.553 ppm (Figure 32), respectively. Thus, tissue means gradually rose during the study period.

At Remediated Zone 2 means were 0.652 (1995), 0.769 (1996), 1.887 (1997), 1.063 (1998), and 2.295 (1999) ppm (Figure 33). Means from Remediated Zone 2 were nearly identical to Zone 1 means. Between 1996 and 1999 means tended to fluctuate within a range of 1 to 2 ppm.

At Unremediated Zone 3 fish were collected from a small tributary to Edmonds Creek located downstream from Remediated Zone 2. There, a post-remediation mean of 0.657 (1995) ppm preceded means of 1.070, 1.819, 0.993, and 1.480 ppm (Figure 34) during 1996 through 1999, respectively. Between 1996 and 1999 means fluctuated within a range of 1 and 2 ppm.

Unremediated Zone 2 and Remediated Zones 3 through 4

These zones are located adjacent to and downstream from OU2. From Unremediated Zone 2, 1995 to 1999 means were 0.502, 0.905, 2.892, 0.797, and 1.528 ppm (Figure 35), respectively. Between 1997 and 1998 means decreased by slightly more than 2 ppm. This result represented the greatest annual decline among any of the zones. From 1996 to 1999 annual means fluctuated between 1 and 3 ppm.

At Remediated Zone 3, the 1995 mean was 0.684 ppm (Figure 36). Subsequently, yearly means fluctuated between 1 and 2 ppm. Results were 1.108 (1996), 1.925 (1997), 0.972 (1998), and 1.672 (1999) ppm.

Downstream from OU2, in Remediated Zone 4, tissue means relatively consistent from year to year. Annual means were 0.724 (1995), 1.129 (1996), 1.384 (1997), 0.899 (1998), and 1.192 ppm (Figure 37). Thus, body burdens have remained relatively stable, near 1 ppm, throughout the monitoring period.

Remediated Zone 5 and Unremediated Zone 1

These zones are located near the mouth of Edmonds Creek. At Remediated Zone 5 means have remained relatively stable, between 1 and 1.5 ppm since 1996. A post-remediation mean of 0.681 (1995) ppm preceded means of 1.345 (1996), 1.564 (1997), 1.382 (1998), and 1.438 ppm (Figure 38). These results produced a similar temporal pattern to that observed at Remediated Zone 5.

Furthest downstream, at Unremediated Zone 1, the mean concentration for the two tissue samples collected in 1995 was 0.754 ppm (Figure 39). In 1996 and 1997 means increased to 1.173 and 1.928 ppm, respectively. Subsequently, as was observed at most of the other zones, the tissue mean then decreased by nearly 1 ppm to 0.988 ppm in 1998. A higher mean of 2.724 ppm was observed in 1999. Thus, tissue concentrations have gradually increased.

Reference Creek Zones

Interestingly, the trends observed at Reference Creek produced a very similar pattern to that observed at Edmonds Creek. Increases in concentrations between 1995 and 1997 were followed by decreases in 1998 within seven of the eight zones (Figures 40 through 47). The highest means/values were again calculated in

1997 suggesting that PCB uptake in the mummichog population from the reference creek were being influenced by a similar set of variables to those in Edmonds Creek. As expected, the results within zones were lower than those observed from Edmonds Creek. All sample means/values fell within a range from less than 0.5 to approximately 2 ppm. Most were 1 ppm or less. In 1999 values for the two samples collected were both below 0.5 ppm.

At the most downstream reference zones, concentrations increased from approximately 0.5 to 1.5 ppm at Zones 1 and 3 from 1995 to 1997 and then decreased to less than 0.5 ppm in 1998. Within Zone 1, 1995 to 1999 results of 0.580 (1995), 0.630 (1996), 1.678 (1997) 0.388 (1998) ppm were followed by a value of 0.434 ppm in 1999 (Figure 40). Tissue concentrations remained constant at Zone 2. Reference Zone 2 was the only location where results remained relatively consistent from year to year. There a 1995 value of 0.814 ppm was followed by results of 0.343 (U), 0.722, and 0.102 ppm (Figure 41) during 1996 through 1998, respectively. At Zone 3 a 1995 mean of 0.412 ppm preceded means of 0.655 (1996), 1.557 (1997), and 0.182 (1998) ppm (Figure 42).

Trends observed near the middle of the study area were very similar to those observed from the Edmonds Creek zones. At Zone 4 tissue results were 0.422 (1995), 0.606 (1996), 1.312 (1997), and 0.234 (1998) ppm (Figure 43) from 1995 to 1998, respectively. An increase occurred between 1996 and 1997 followed by a decrease in 1998. A temporal increase between 1995 and 1997 also occurred at Zone 5 but was more gradual. There, 1995 to 1998 results were 0.301, 0.550, 0.716, and 0.338 ppm (Figure 44), respectively. In 1998 the tissue mean was close to the post-remediation value measured in 1995. Within Zone 6, 1995 through 1997 results were 0.420, 0.595, and 1.652 ppm (Figure 45), respectively. The 1998 mean then decreased to 0.180 ppm.

Furthest upstream, at Reference Zones 7 and 8, PCB concentrations continued to rise from 1995 to 1997, and then declined. Temporal increases were observed at both zones. At Zone 7 a 1995 mean of 0.288 ppm increased to 0.980 ppm (Figure 46) in 1997. Nearly identical results were obtained from Zone 8 where a 1995 mean of 0.260 ppm was followed by a value of 0.958 ppm in 1997 (Figure 47). Tissue means then decreased at both zones. In 1998 a value of 0.181 was obtained at Zone 7 and results of 0.334 (1997) and (0.228) were obtained at Zone 8.

Edmonds Creek and Reference Creek Cumulative Means

The following table lists annual cumulative means, from all Edmonds Creek and Reference Creek zones combined, for each sample matrix. Values are expressed as parts per million rounded to the nearest tenth. Please note that the 1996 results for the macoma clams contain a positive bias due to mortality incurred during the exposure period and resultant loss of tissue available for analysis. These values are marked with an asterisk. The bias was most pronounced for the results obtained from the reference area because none of the Aroclors were detectable there during 1996. Aroclors 1248 and/or 1254 were detectable from most of the tissue samples collected from Edmonds Creek in 1996 so those results were more representative.

Edmonds Creek:

Year	Sediment	Fiddler Crabs	Macoma Clams	Mummichogs
1995	0.6 ppm	1.4 ppm	0.8 ppm	0.7 ppm
1996	2.9 ppm	1.8 ppm	1.4* ppm	1.1 ppm
1997	3.9 ppm	1.6 ppm	0.9 ppm	1.9 ppm
1998	3.9 ppm	1.3 ppm	0.5 ppm	1.0 ppm
1999	5.3 ppm	1.2 ppm	0.7 ppm	1.9 ppm

Reference Creek:

Year	Sediment	Fiddler Crabs	Macoma Clams	Mummichogs
1995	0.3 ppm	0.2 ppm	0.1 ppm	0.4 ppm
1996	2.9 ppm	0.1 ppm	1.2* ppm	0.6 ppm
1997	0.5 ppm	0.5 ppm	< 0.1 ppm	1.2 ppm
1998	0.6 ppm	0.1 ppm	< 0.1 ppm	0.2 ppm
1999	0.5 ppm	< 0.1 ppm	< 0.1 ppm	0.3 ppm

Cumulative measurements from Edmonds Creek show that the sediment means have gradually risen during the study period. Note that when the mean of 16.535 ppm from Unremediated Zone 2 is excluded from the calculation the cumulative mean for the rest of the study area becomes 3.5 ppm. Results from the invertebrate tissue analyses were encouraging. A slight downward trend has been observed at Edmonds Creek from both the fiddler crab and macoma clam data indicating that the remediation effort was successful. The mummichog data fluctuated from year to year and did on not show any directional trend after 1995. Cumulative means were near 2 ppm in 1997 and 1999 and near 1 ppm in 1996 and 1998.

Results from Reference Creek were consistent from year to year for each matrix.

Table 5a. Kin-Buc Project - Mummichog tissue PCB concentrations from 1999 (year 5) samples collected from Edmonds Creek.

Sample ID Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Edmonds Creek Zones:										
Rem Zone 1:										
F-01J	25 U	60 U	70 U	55 U	1,310	360	101 J	1,981	79.2	2.5
F-01J Dup	25 U	60 U	70 U	55 U	1,250	370	104 J	1,934	89.9	2.2
F-01A	25 U	60 U	70 U	55 U	2,310	530	99 J	3,149	101.6	3.1
							Mean	2,553	93.1	
							Std. error of the mean	596	8.5	
							Coefficient of Variation	33.0%	12.9%	
Rem Zone 2:										
F-02J	25 U	60 U	70 U	55 U	1,180	350	99 J	1,839	83.6	2.2
F-02A	25 U	60 U	70 U	55 U	1,890	500	151 J	2,751	131.0	2.1
							Mean	2,295	107.3	
							Std. error of the mean	456	23.7	
							Coefficient of Variation	28.1%	31.2%	
Unrem Zone 3:										
UN-F-03J	5 U	12 U	14 U	10 U	614	285	76	1,016	56.4	1.8
UN-F-03A	12 U	30 U	35 U	26 U	1,230	470	140	1,943	72.0	2.7
							Mean	1,480	64.2	
							Std. error of the mean	464	7.8	
							Coefficient of Variation	44.3%	17.2%	
Unrem Zone 2:										
UN-F-02J	5 U	12 U	14 U	10 U	666	364	101	1,172	53.3	2.2
UN-F-02A	12 U	30 U	35 U	26 U	1,160	450	119	1,832	83.3	2.2
UN-F-02A Dup	12 U	30 U	35 U	26 U	1,260	450	124 J	1,937	69.2	2.8
							Mean	1,528	64.8	
							Std. error of the mean	356	11.5	
							Coefficient of Variation	33.0%	25.0%	

Table 5a. continued.

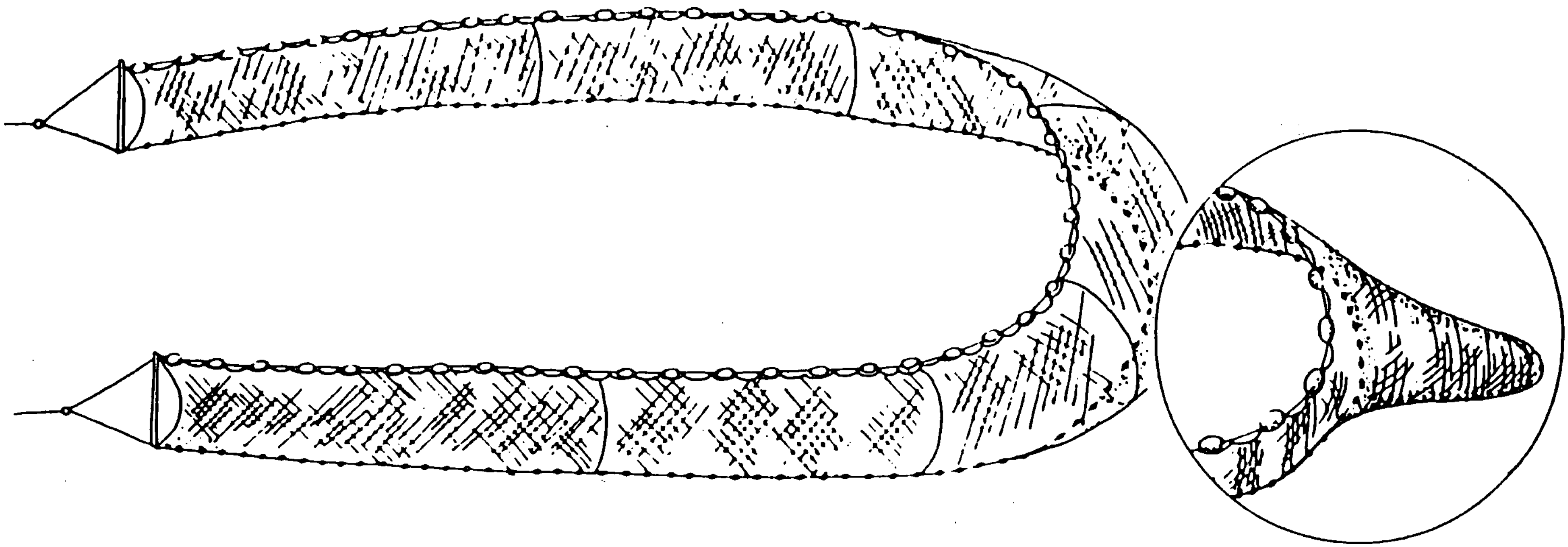
Sample ID Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Rem Zone 3:										
F-03J	12 U	30 U	35 U	26 U	790	380	107 J	1,380	72.6	1.9
F-03A	12 U	30 U	35 U	26 U	1,250	480	130	1,963	70.1	2.8
							Mean	1,672	71.4	
							Std. error of the mean	292	1.3	
							Coefficient of Variation	24.7%	2.5%	
Rem Zone 4:										
F-04J	5 U	12 U	14 U	10 U	384	193	54	672	42.0	1.6
F-04A	12 U	30 U	35 U	26 U	1,010	470	130	1,713	90.2	1.9
							Mean	1,192	66.1	
							Std. error of the mean	521	24.1	
							Coefficient of Variation	61.8%	51.6%	
Rem Zone 5:										
F-05J	12 U	30 U	35 U	26 U	630	480	150	1,363	104.8	1.3
F-05A	12 U	30 U	35 U	26 U	730	510	170	1,513	108.1	1.4
							Mean	1,438	106.4	
							Std. error of the mean	75	1.7	
							Coefficient of Variation	7.4%	2.2%	
Unrem Zone 1:										
UN-F-01J	25 U	60 U	70 U	55 U	1,550	870	238 J	2,868	179.2	1.6
UN-F-01A	25 U	60 U	70 U	55 U	1,250	850	270	2,580	151.8	1.7
							Mean	2,724	165.5	
							Std. error of the mean	144	13.7	
							Coefficient of Variation	7.5%	11.7%	

Notes: 1) One-half detection limit was assumed for U-qualified data.
2) Estimated results between the minimum detection limit and the limit of quantitation are J-qualified.

Table 5b. Kin-Buc Project - Mummichog tissue PCB concentrations from 1999 (year 5) samples collected from Reference Creek.

Sample ID Number	PCB Tissue Concentration (µg/kg wet weight) A1016	A1221	A1232	A1242	A1248	A1254	A1260	Sum of Aroclors (µg/kg wet wt)	Normalized sum of Aroclors (µg/g lipid)	Percent Lipid
Reference Creek Zones:										
Ref Zone 1:										
RA-F-01A	5 U	12 U	14 U	10 U	114	180	99	434	21.7	2.0
							Mean	434	21.7	
							Std. error of the mean	-	-	
							Coefficient of Variation	-	-	
Ref Zone 8:										
RA-F-08A	5 U	12 U	14 U	10 U	56	75	56	228	6.2	3.7
							Mean	228	6.2	
							Std. error of the mean	-	-	
							Coefficient of Variation	-	-	

Notes: 1) One-half detection limit was assumed for a U-qualified data.



NORMANDEAU ASSOCIATES ENVIRONMENTAL CONSULTANTS 3450 Schuylkill Road Spring City, PA 19475-1124	FIGURE 31. HAUL SEINE	DATE: 12-17-96
		JOB NO.: 16148.001
		SCALE: NOT TO SCALE

Figure 32. Five year PCB trend for mummichog tissue samples collected from Remediated Zone 1 near Kin-Buc Landfill.

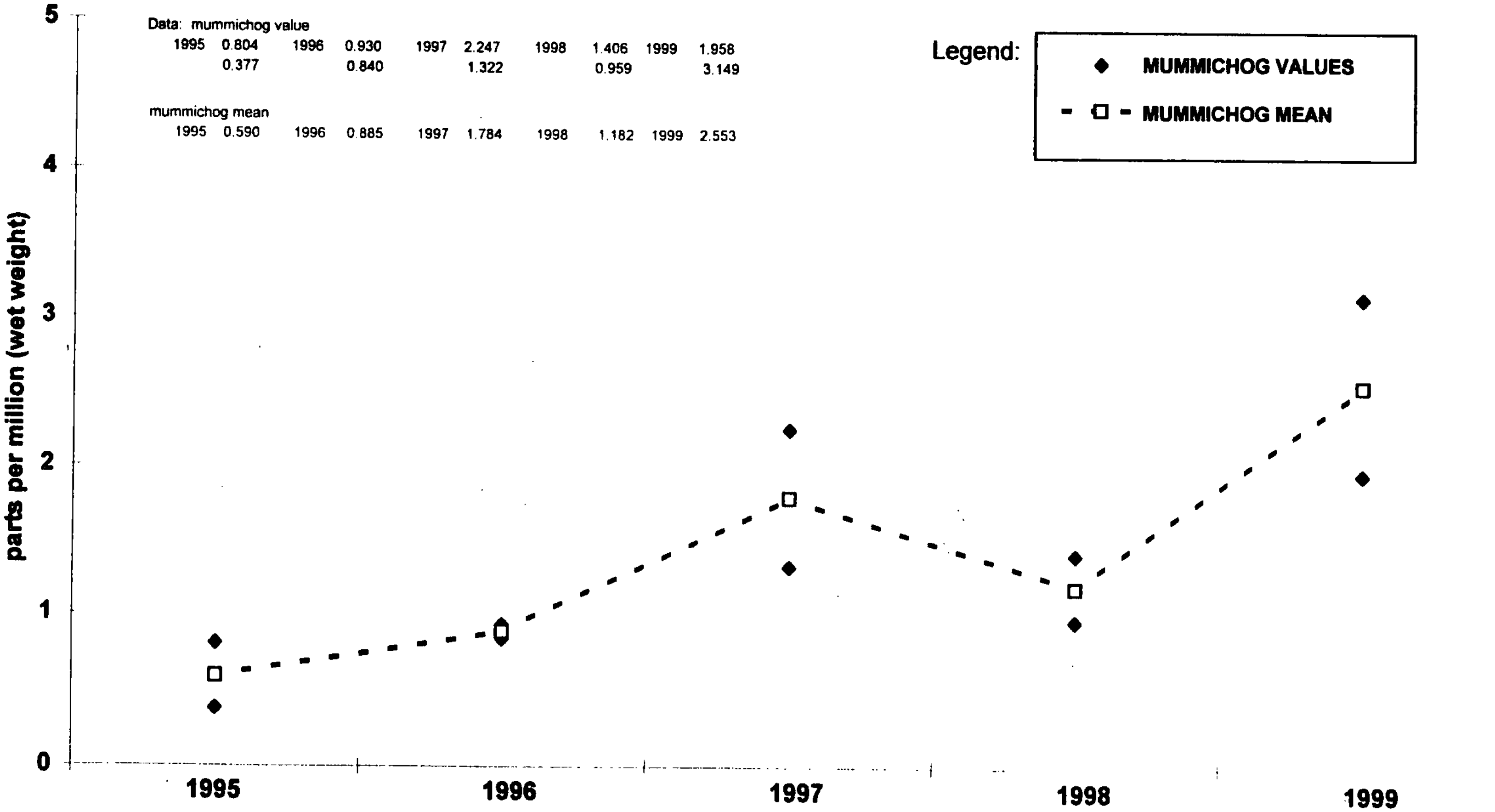


Figure 33. Five year PCB trend for mummichog tissue samples collected from Remediated Zone 2 near Kin-Buc Landfill.

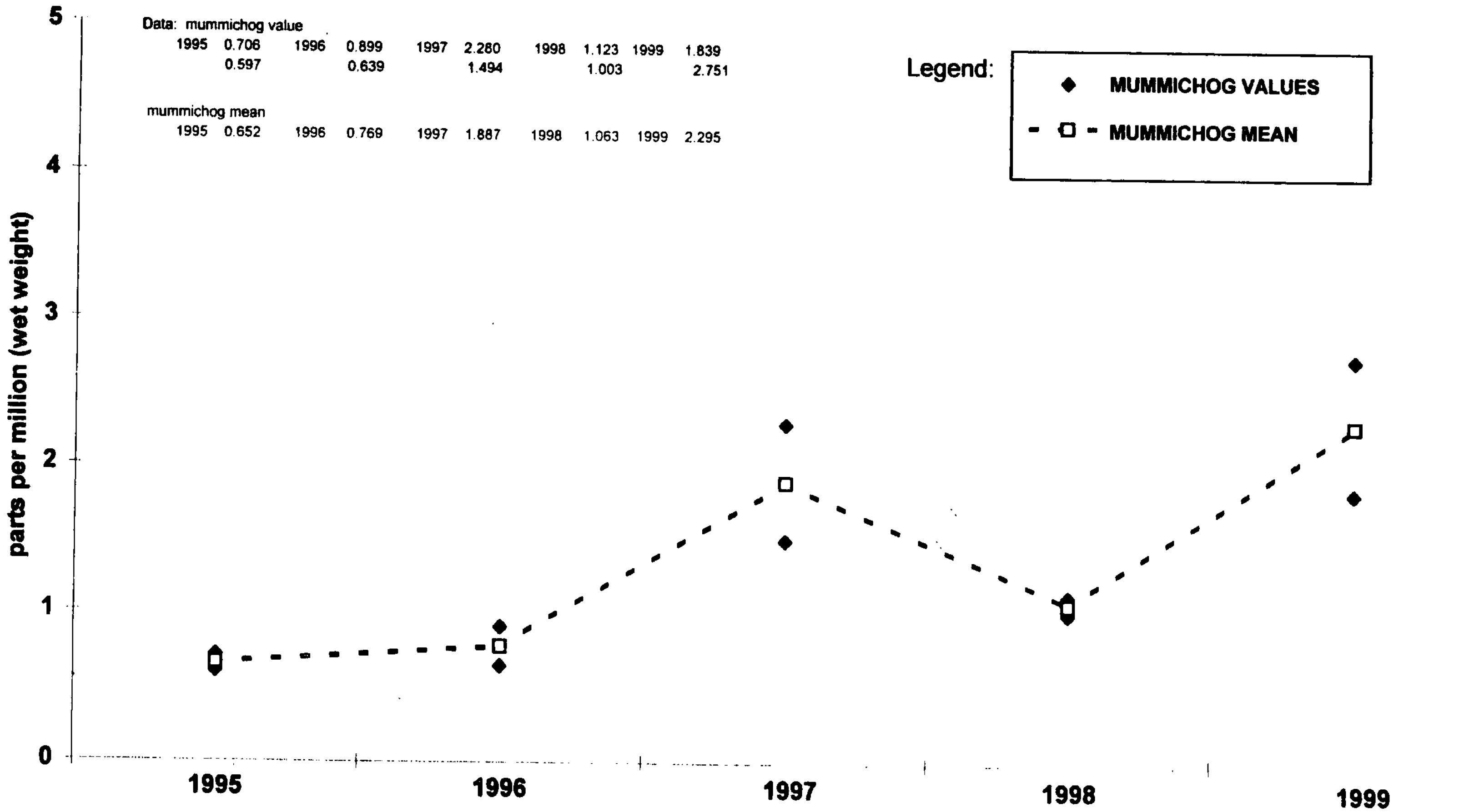


Figure 34. Five year PCB trend for mummichog tissue samples collected from Unremediated Zone 3 near Kin-Buc Landfill.

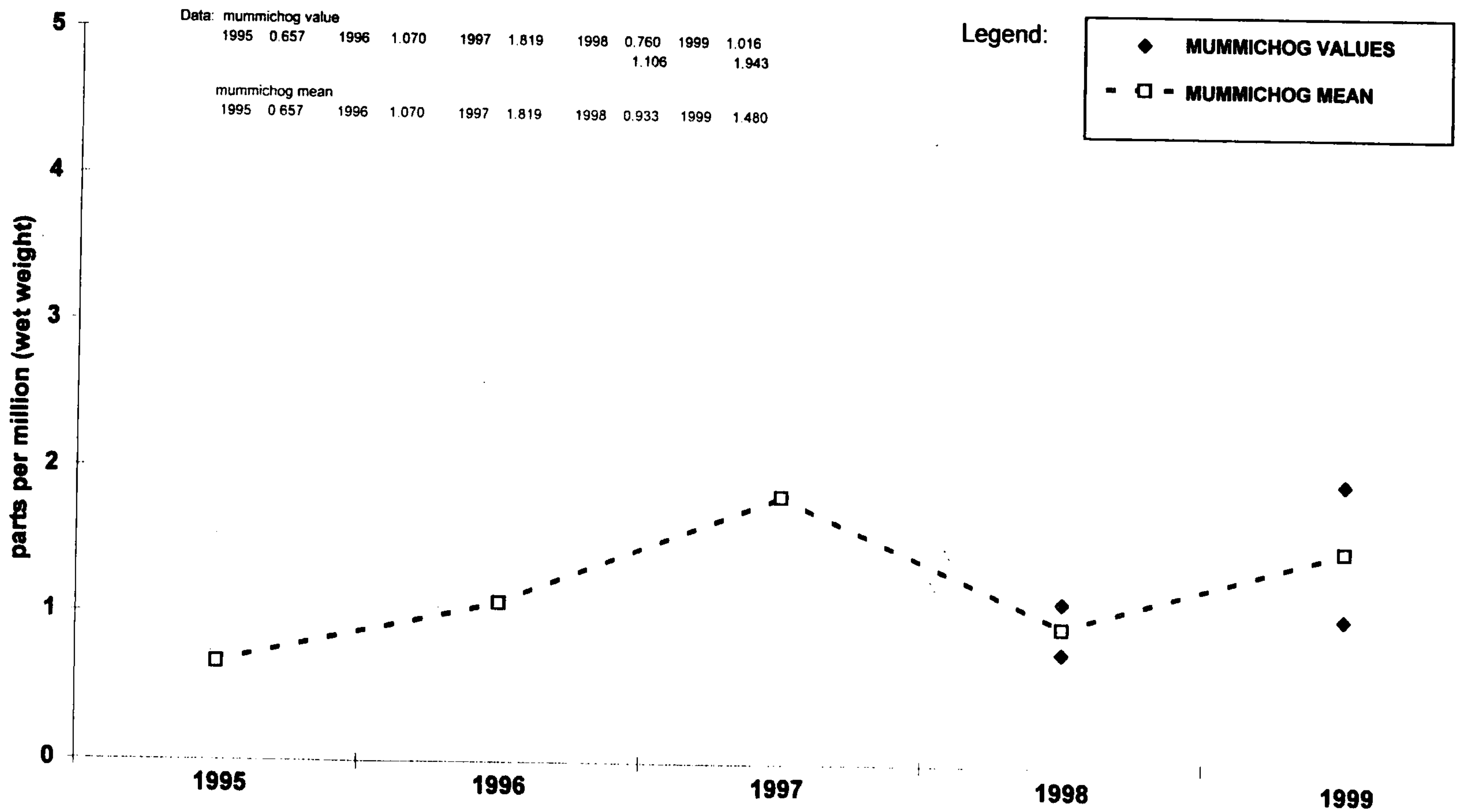


Figure 35. Five year PCB trend for mummichog tissue samples collected from Unremediated Zone 2 near Kin-Buc Landfill.

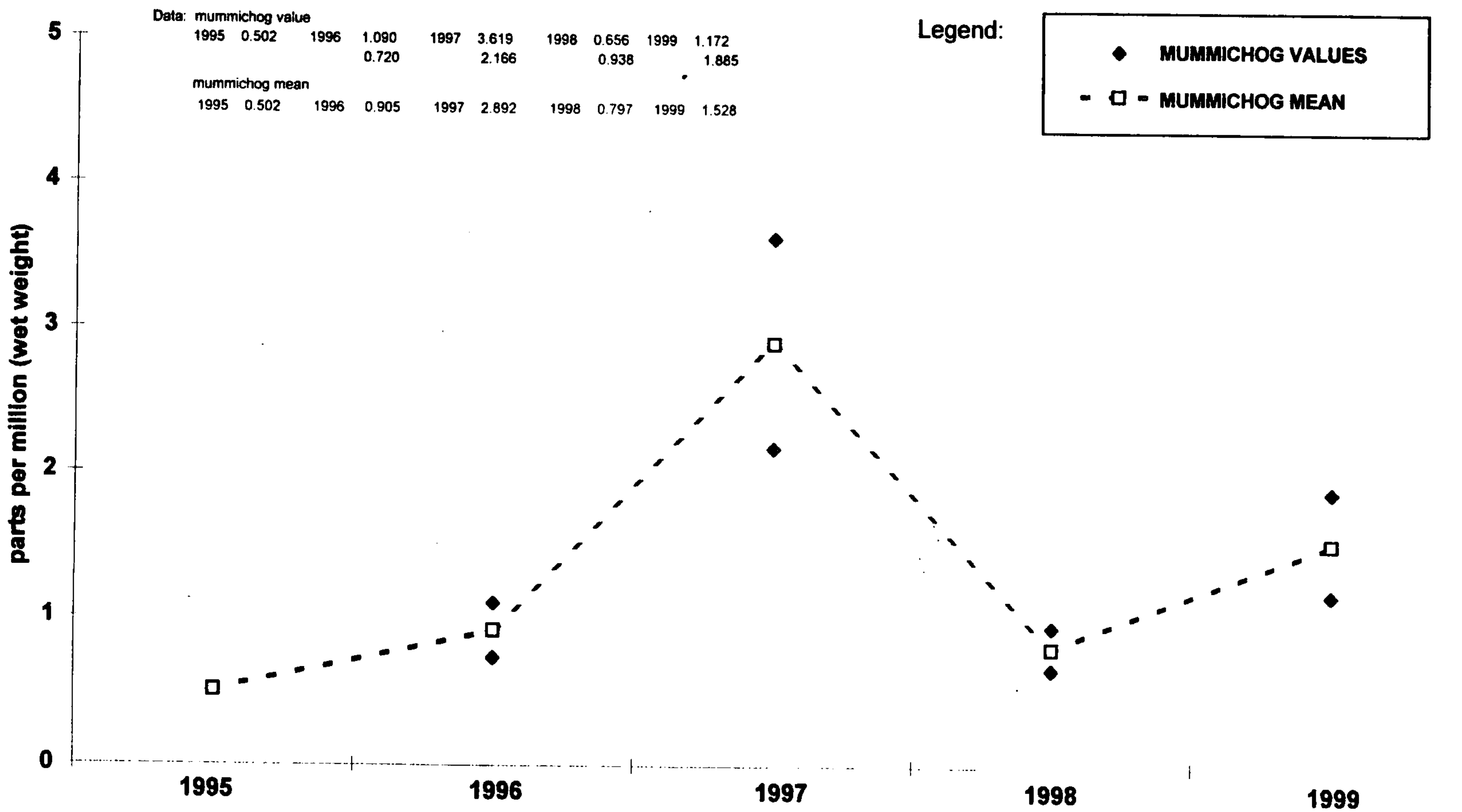


Figure 36. Five year PCB trend for mummichog tissue samples collected from Remediated Zone 3 near Kin-Buc Landfill.

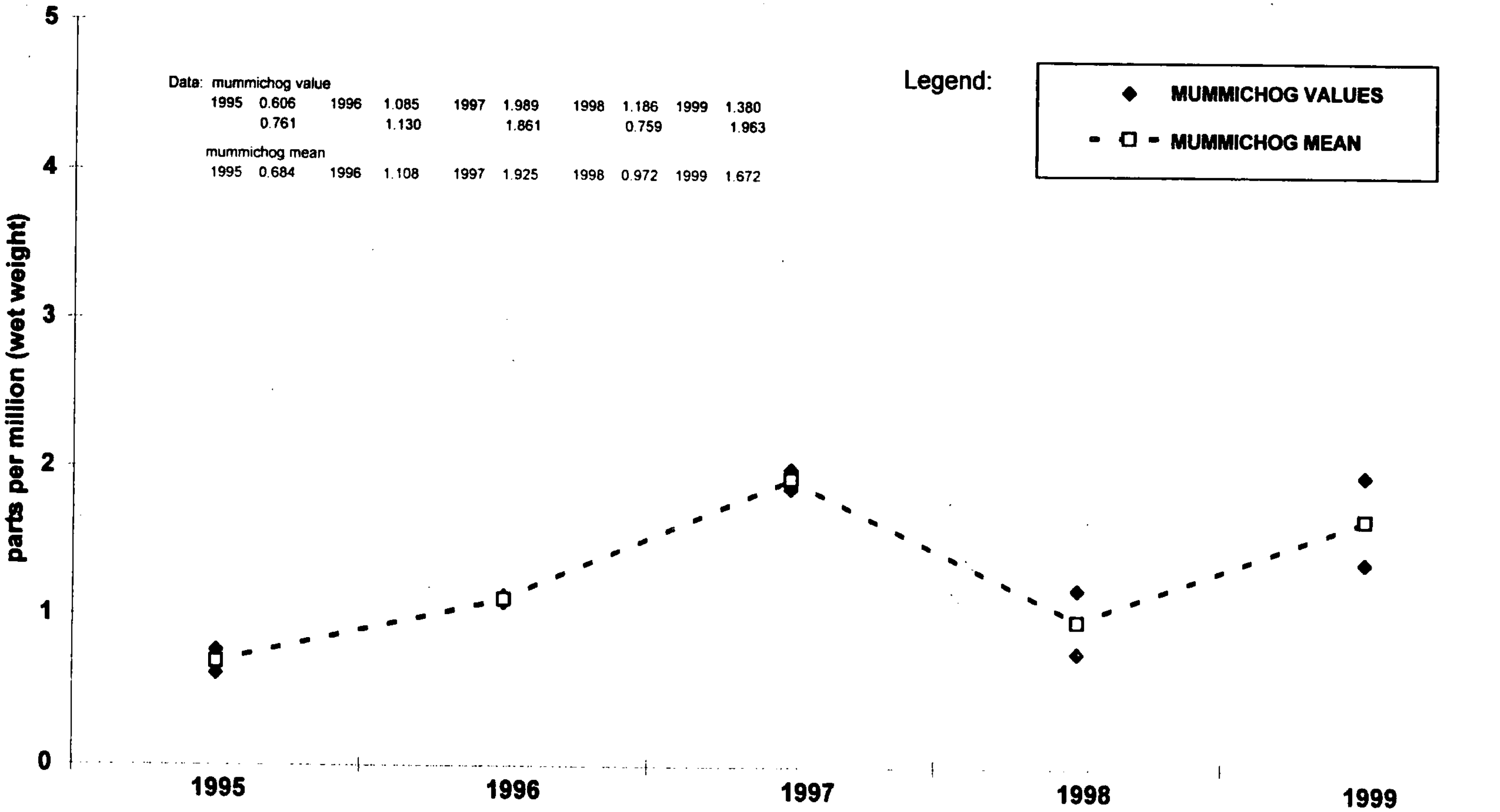


Figure 37. Five year PCB trend for mummichog tissue samples collected from Remediated Zone 4 near Kin-Buc Landfill.

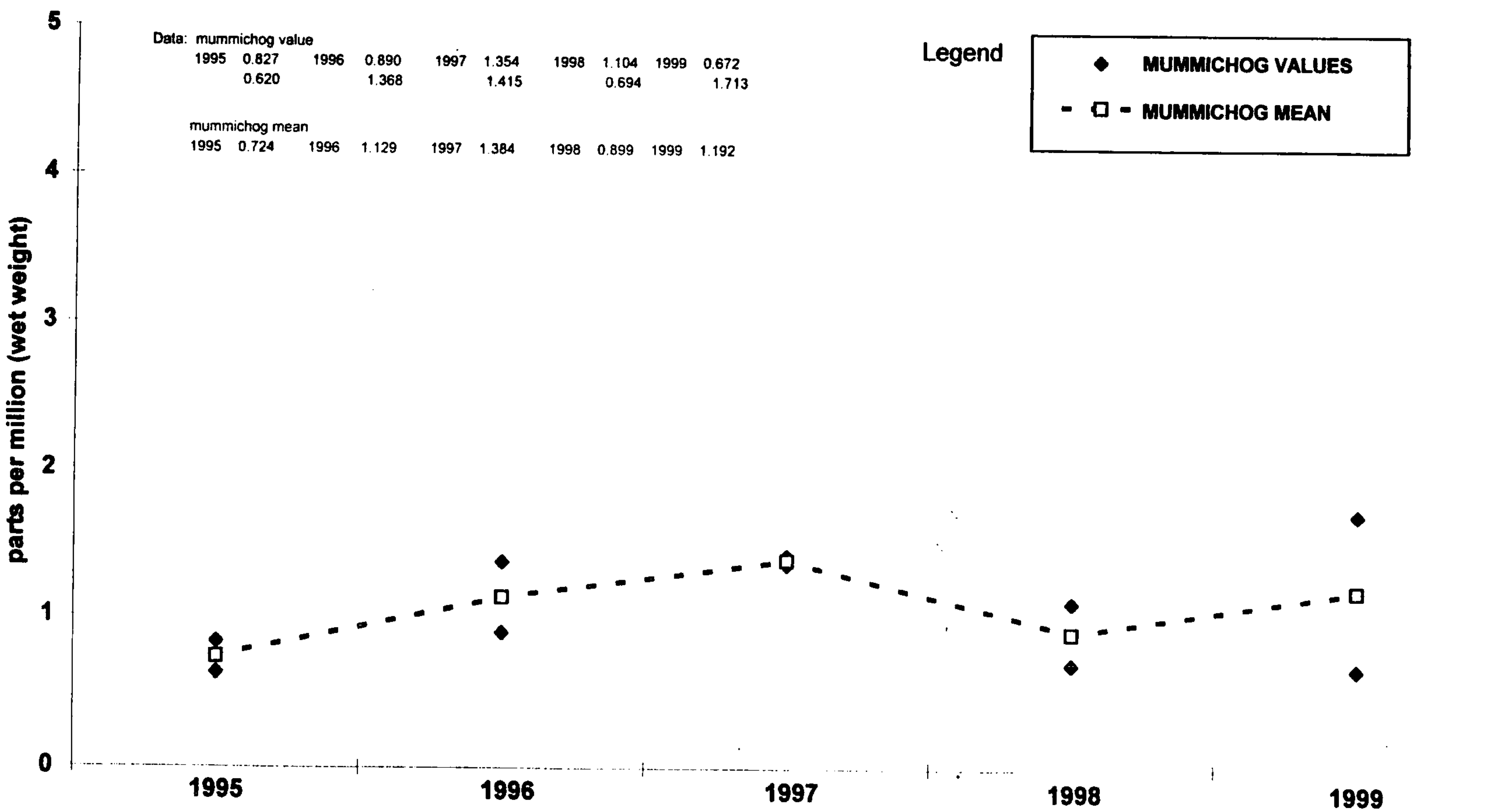


Figure 38. Five year PCB trend for mummichog tissue samples collected from Remediated Zone 5 near Kin-Buc Landfill.

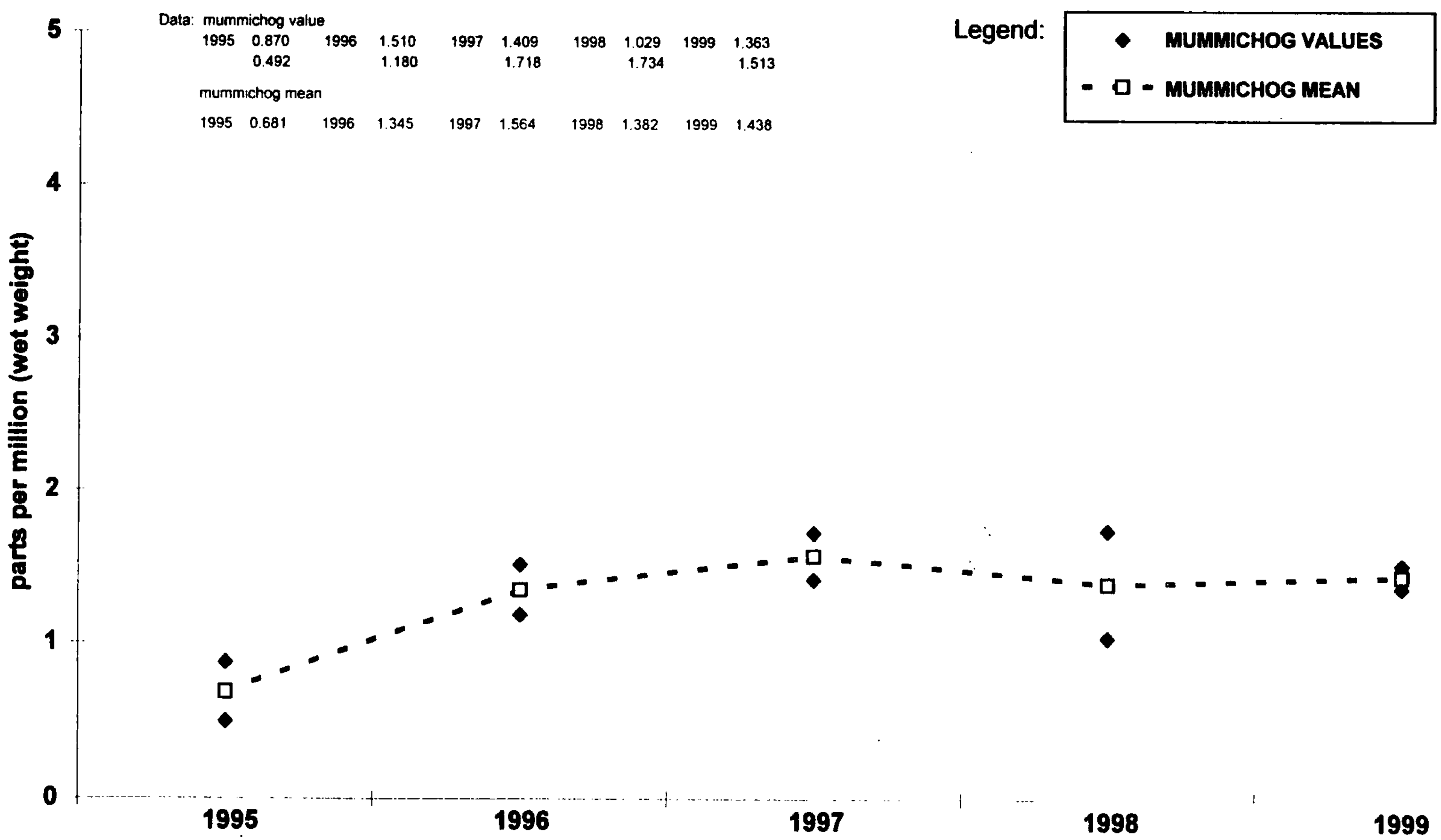


Figure 39. Five year PCB trend for mummichog tissue samples collected from Unremediated Zone 1 near Kin-Buc Landfill.

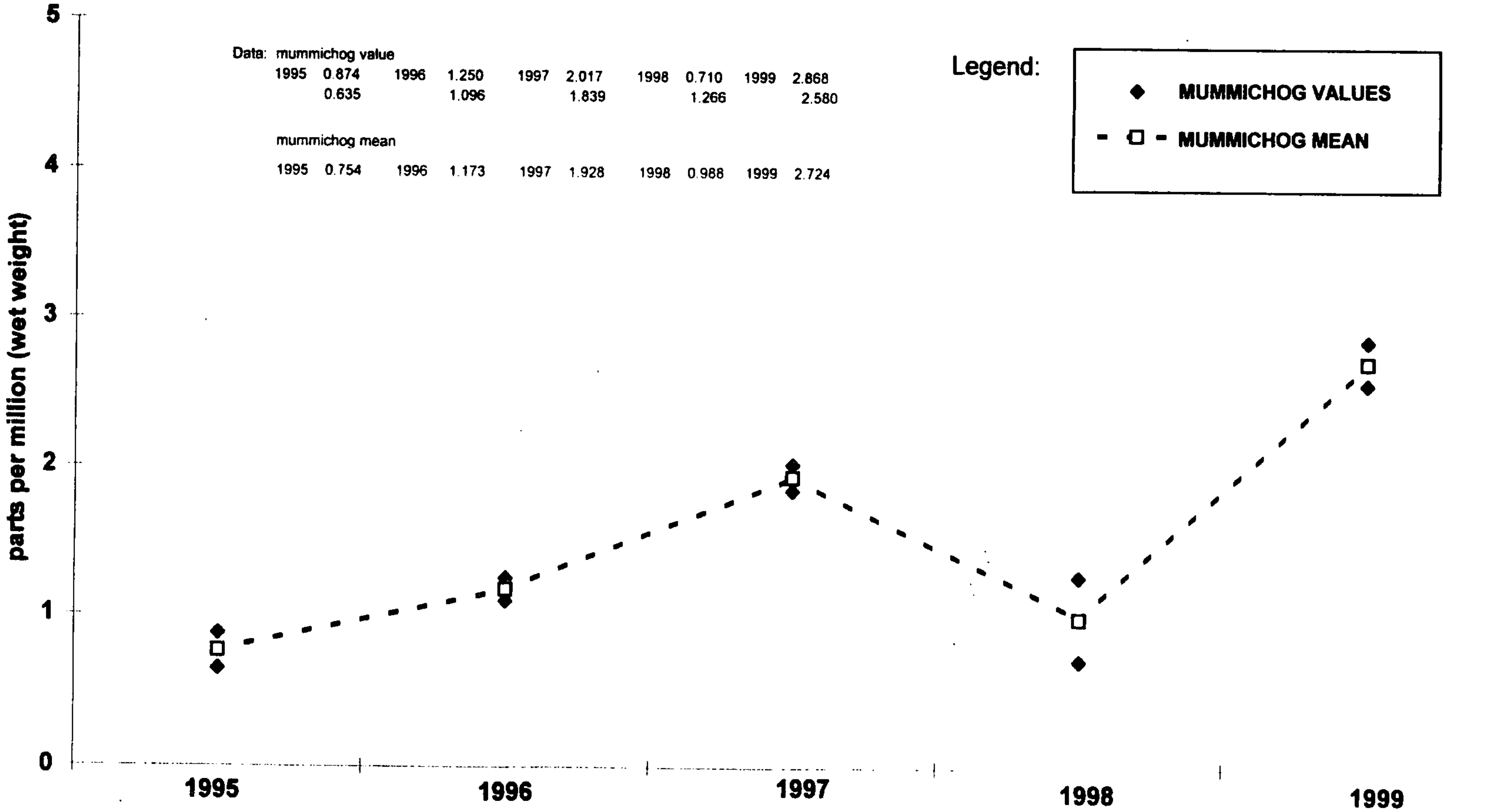


Figure 40. Five year PCB trend for mummichog tissue samples collected from Reference Zone 1 near Kin-Buc Landfill.

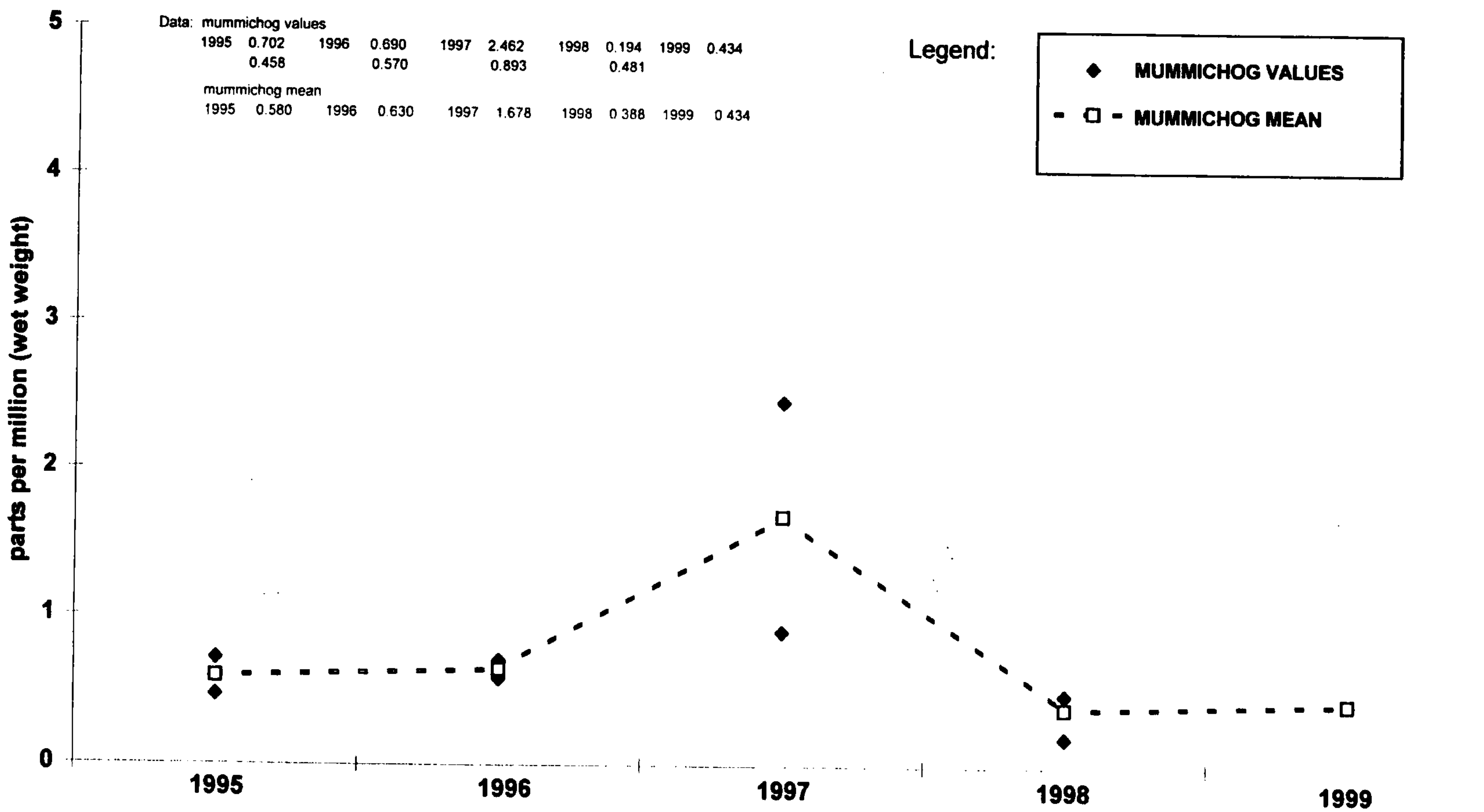
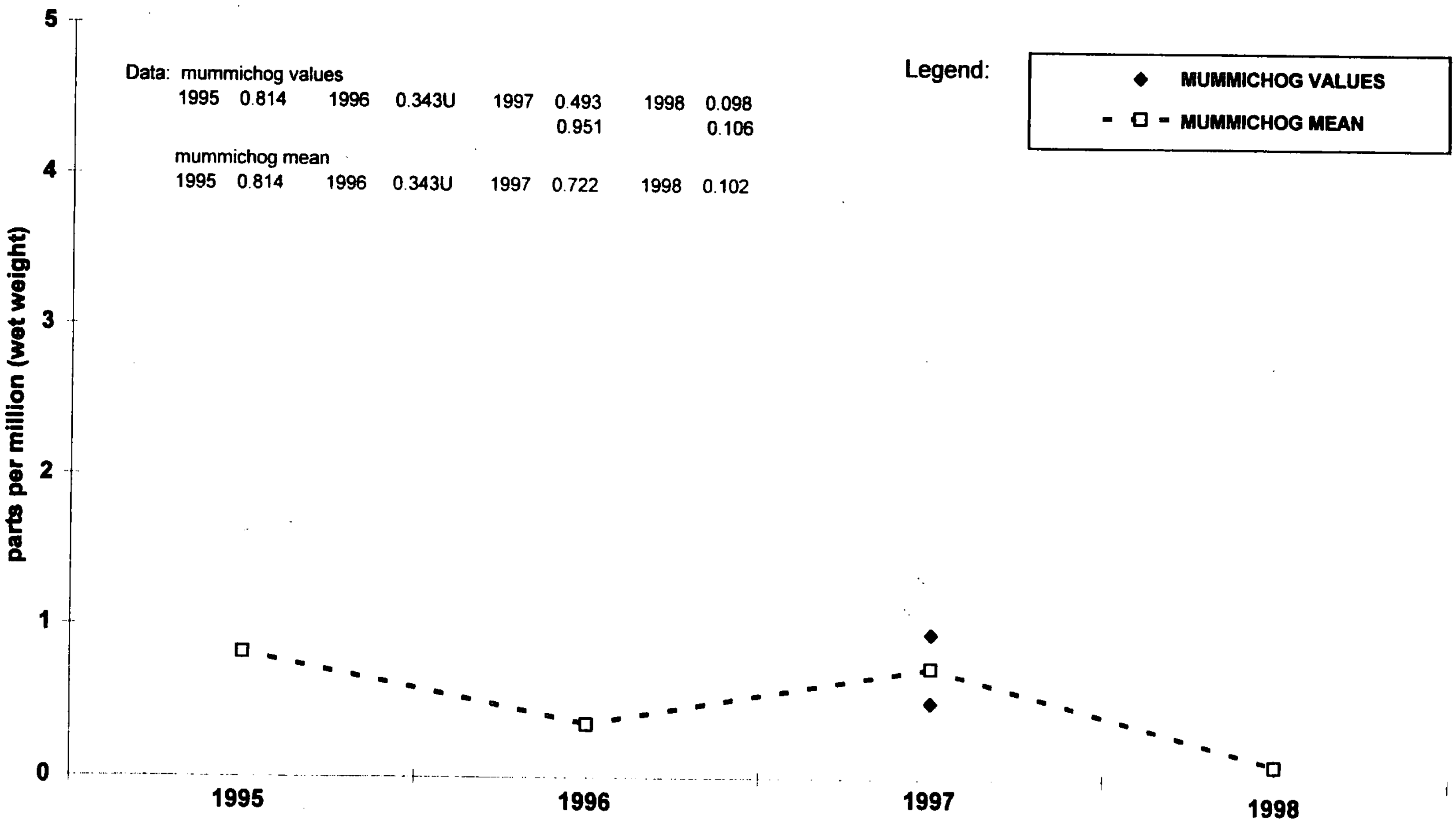


Figure 41. Four year PCB trend for mummichog tissue samples collected from Reference Zone 2 near Kin-Buc Landfill.



Note: 1) One-half detection limit was assumed for U-qualified data.

Figure 42. Four year PCB trend for mummichog tissue samples collected from Reference Zone 3 near Kin-Buc Landfill.

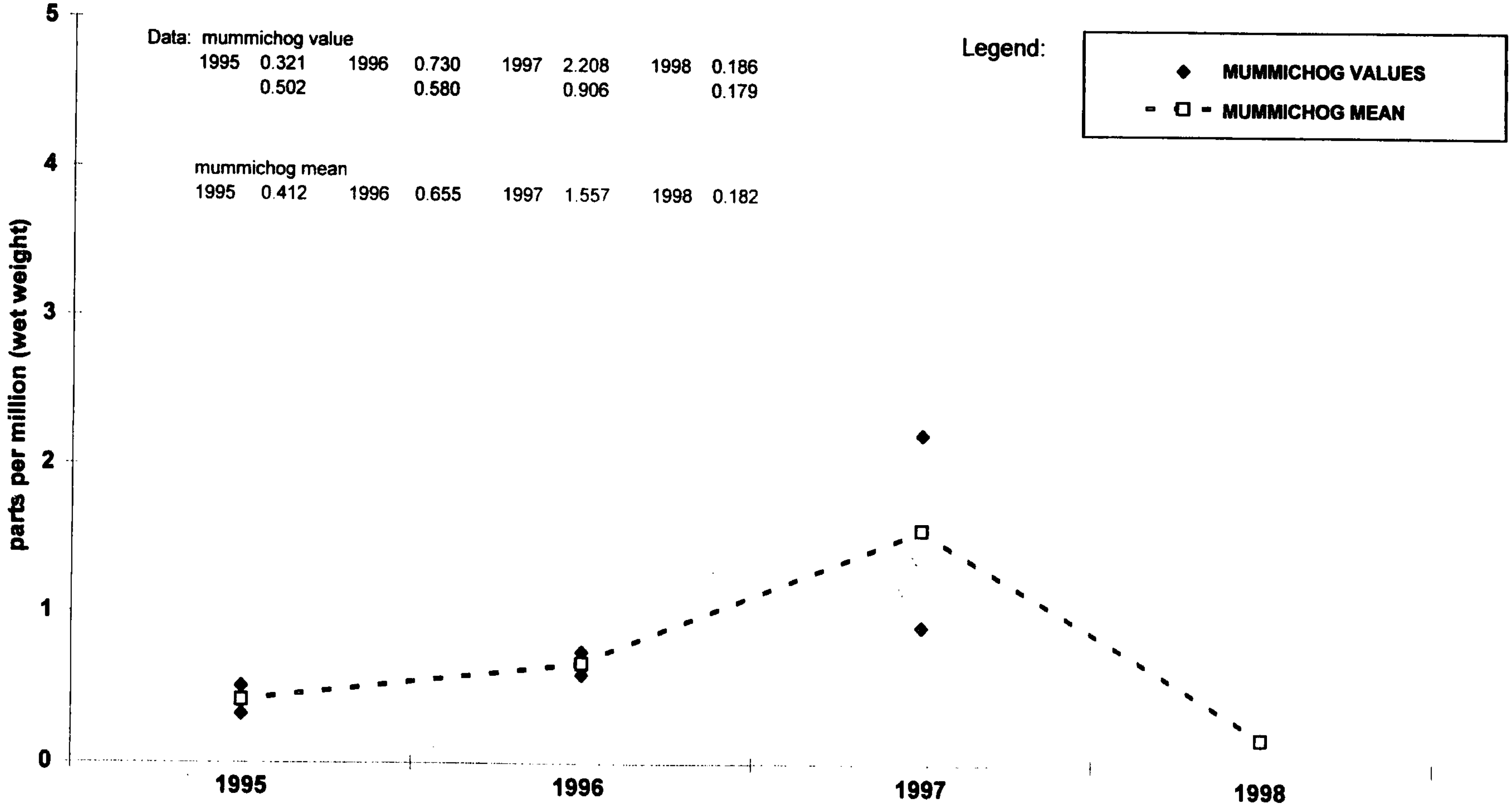


Figure 43. Four year PCB trend for mummichog tissue samples collected from Reference Zone 4 near Kin-Buc Landfill.

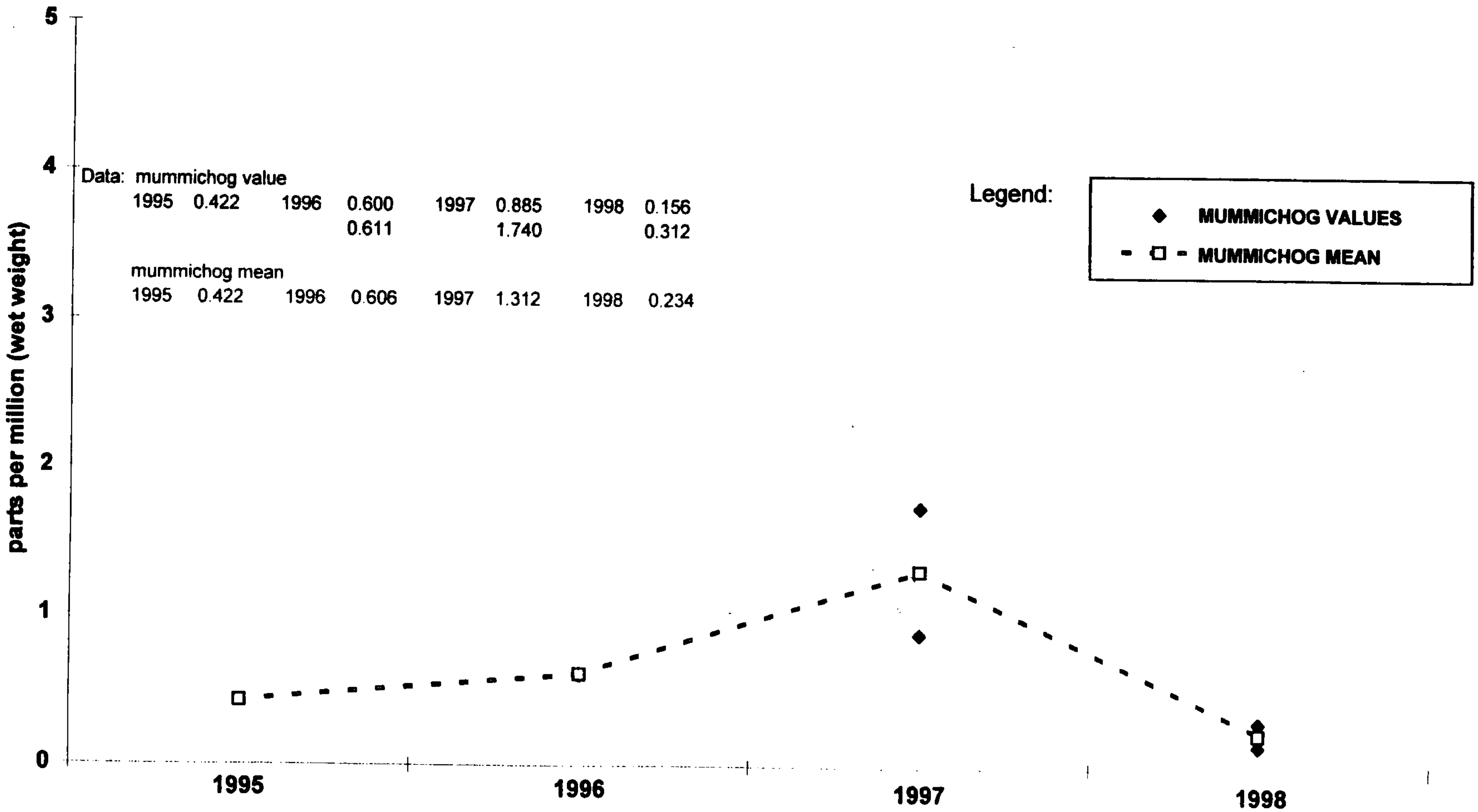


Figure 44. Four year PCB trend for mummichog tissue samples collected from Reference Zone 5 near Kin-Buc Landfill.

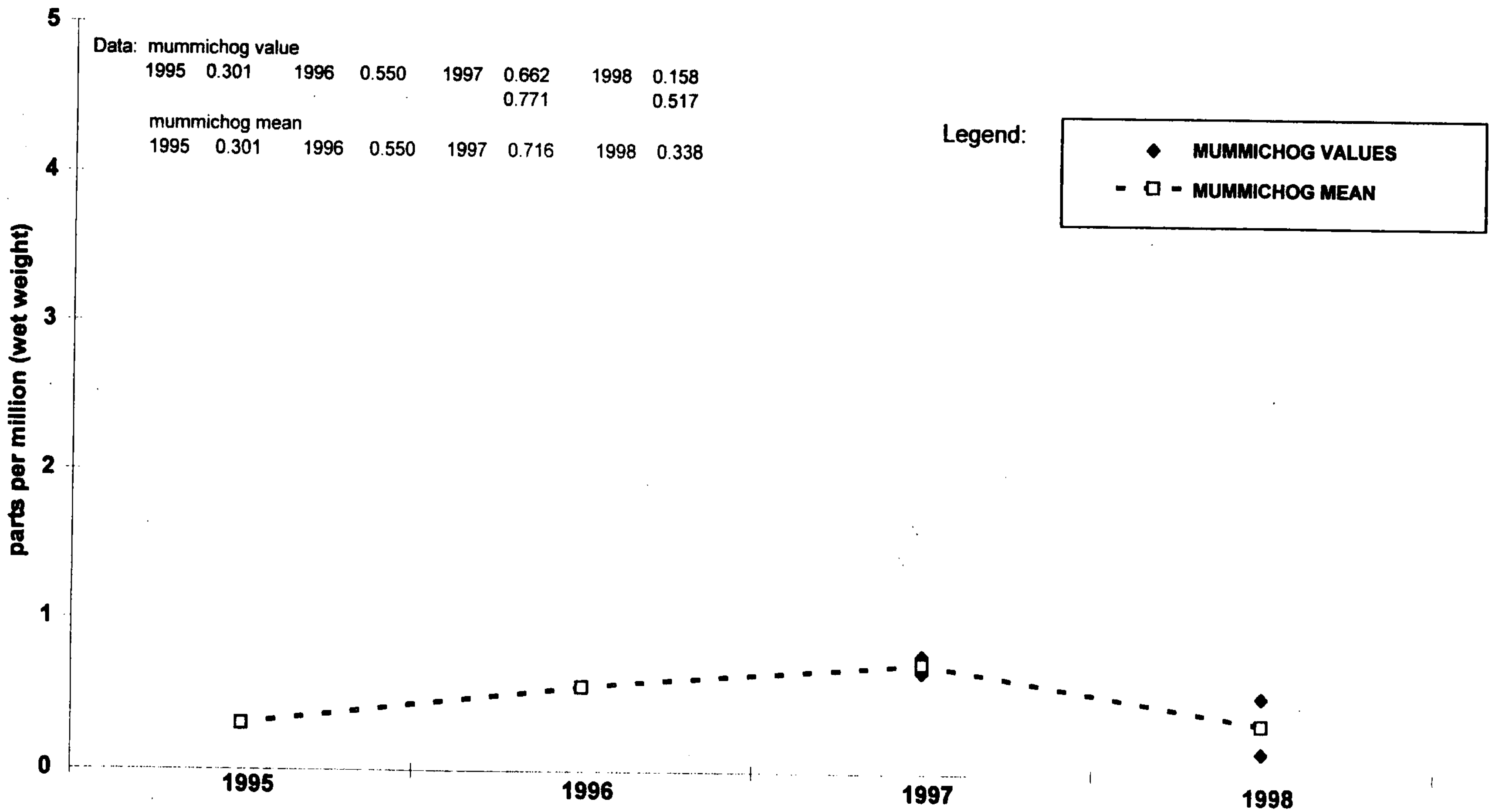


Figure 45. Four year PCB trend for mummichog tissue samples collected from Reference Zone 6 near Kin-Buc Landfill.

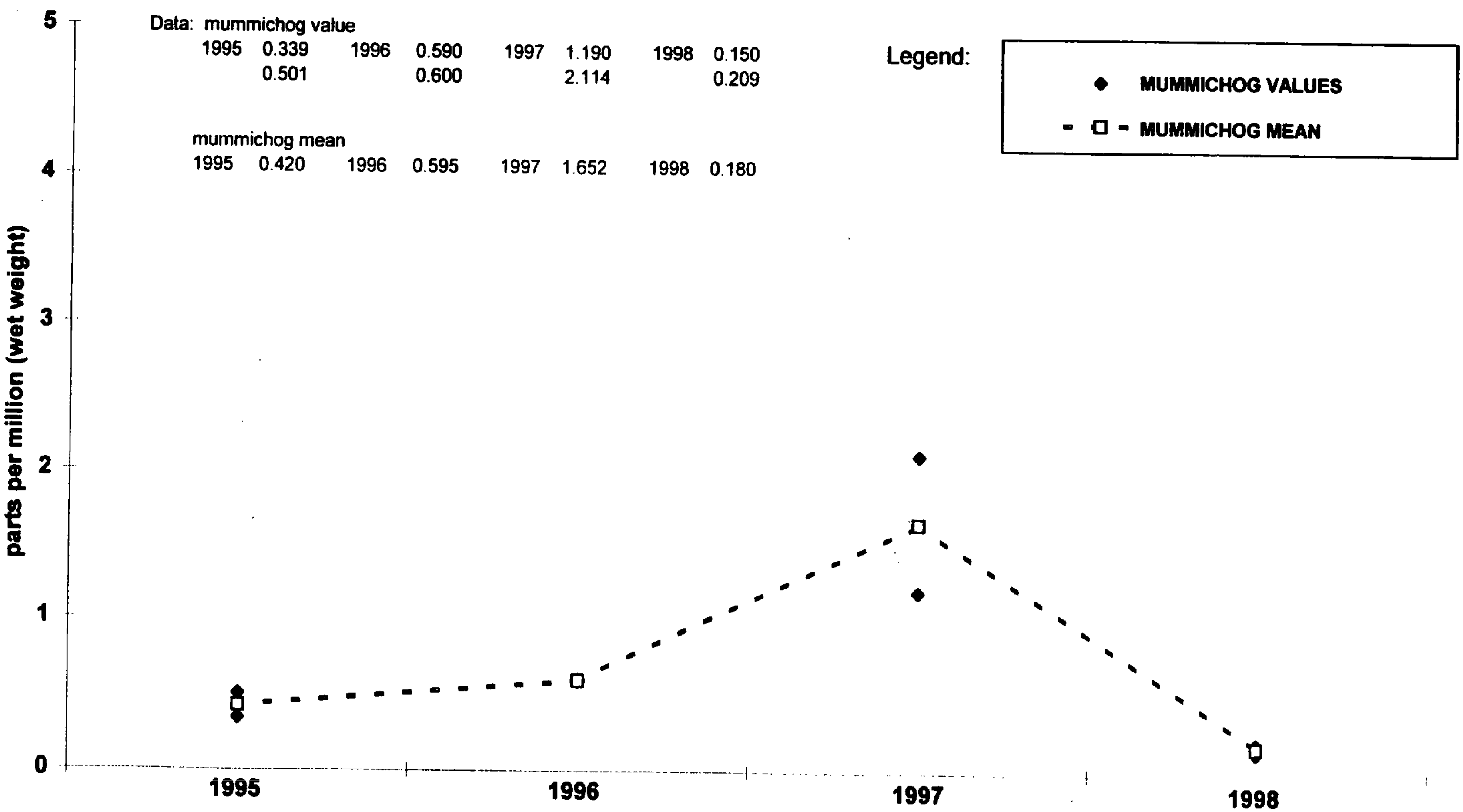


Figure 46. Four year PCB trend for mummichog tissue samples collected from Reference Zone 7 near Kin-Buc Landfill.

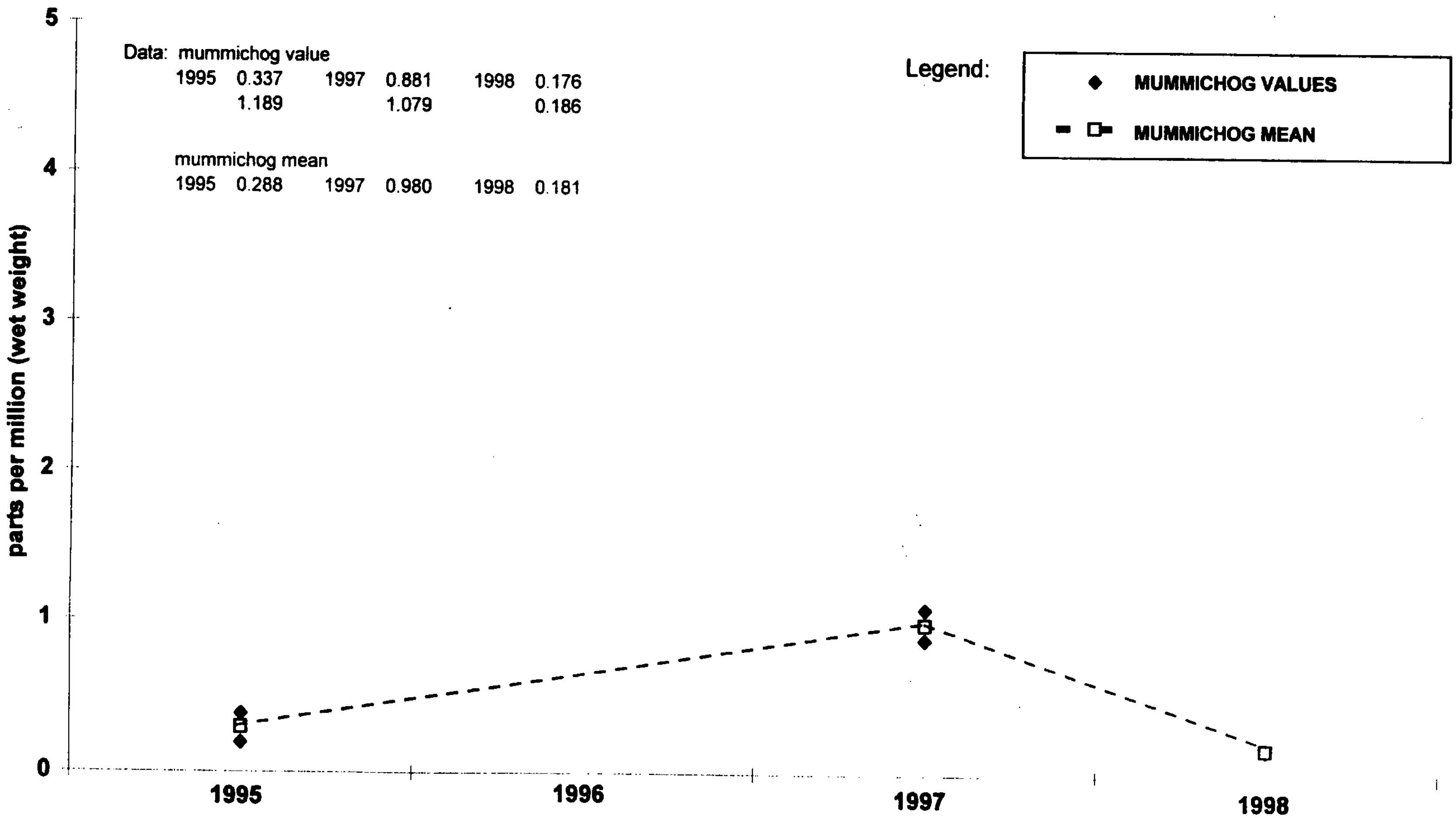
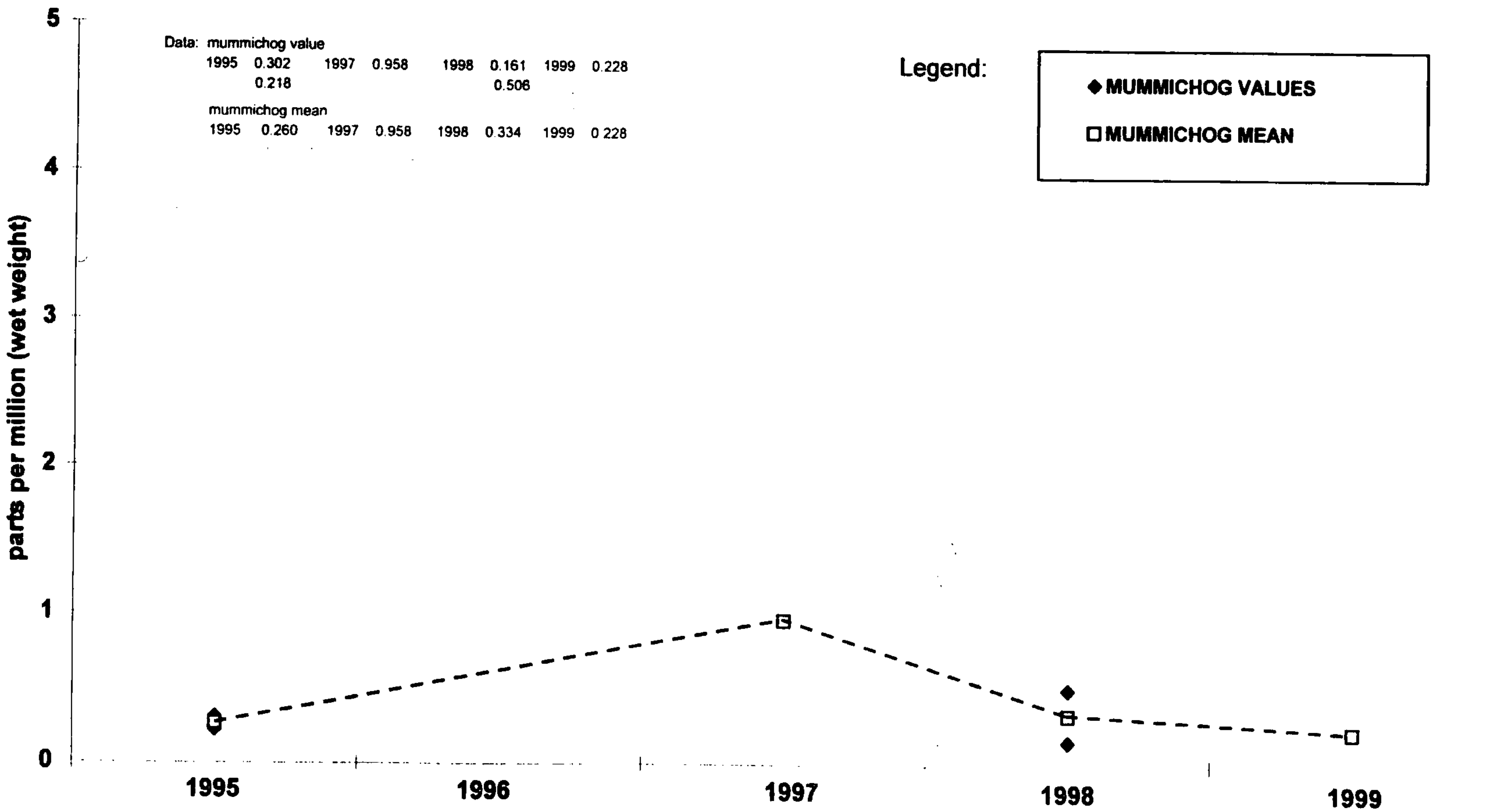


Figure 47. Five year PCB trend for mummichog tissue samples collected from Reference Zone 8 near Kin-Buc Landfill.



7.0 BENTHIC MACROINVERTEBRATE AND FISH RE-COLONIZATION

Benthic macroinvertebrates are small aquatic organisms that live on or burrow within the substrates of lakes and streams. They are commonly referred to as insects, crustaceans, worms, and mollusks. They are relatively immobile and susceptible to chemical degradation in water and/or sediment quality, and to physical disturbance of the substrates in which they reside. Quick responders, they have been used for many years in ecological studies as biotic measures of habitat and water quality. Here, invertebrate data are used in conjunction with fisheries data from the seine collections to document the re-establishment of viable aquatic communities at Edmonds Creek following excavation of the contaminated sediments.

7.1 Materials and Methods

Collection

Invertebrate samples were collected on 31 August and 1 September 1999, and analyzed according to procedures adapted from US EPA, 1990; entitled, "Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters" (EPA/600/4-90/030). Invertebrate samples were collected with a Petite Ponar from eighteen transects crossing the two streams. Each grab enclosed a 0.023 square meter (six inches square) area of substrate. Fourteen transects were sampled from five remediated and two unremediated zones (two per zone) in Edmonds Creek and four transects were sampled from two zones in Reference Creek. Transect locations are shown on Drawings 1 and 1.5. At each transect composite samples consisting of three grabs each were collected from sublocations representing "intertidal vegetated", "intertidal mud", and "subtidal" habitats. In total, thirty discrete samples were collected from remediated zones, and twelve each from unremediated and reference zones. Each sample was sieved in the field through a 0.500-millimeter mesh, and the retained portion placed into sample containers. Each sample was preserved with 70 percent isopropanol and transported to the lab for processing. Field data recorded during the invertebrate collections included descriptions of the sediment, organic content, odor, the presence of oils, and the identity of any dominant types (e.g., worms, clams, etc.) of easily observable organisms. Water depth, water clarity, temperature, dissolved oxygen, pH, salinity, and conductivity were also measured at each transect. Where subtidal depth was greater than 1.5 meters the chemical measurements were repeated over a one-meter interval. Where subtidal depth was less than 1.5 meters measurements were made at mid-depth.

Fish collections were made with an 8-foot block seine as described in Section 6.1.

Sample Processing

At the lab, preservative was removed from the samples and the contents (invertebrates plus a sample matrix consisting of sediments and detritus larger than 0.500 mm diameter) resieved. The sample matrices were then placed in white enamel pans and the invertebrates removed and sorted by type into glass vials containing preservative. The sample matrices were processed in entirety.

Following removal, the specimens were identified to lowest distinct taxonomic classification possible given their age and condition (called a taxon). Dissecting (45x magnification) and compound microscopes (500x magnification) were used to view and identify the invertebrates. Tubificids and chironomids were cleared with Ammons lactophenyl or 10 percent potassium hydroxide, as applicable, and slide mounted prior to identification. The most current taxonomic literature available was used to identify the specimens.

Analysis

To analyze the invertebrate community the data were reduced to a set of five ecological metrics. The metrics were: taxonomic richness, community density, percent contribution of the dominant taxon, Brillouin's diversity, and Brillouin's evenness. Richness is defined as the number of taxa identified from each sample. Healthy communities usually include a variety of taxa. Density is the number of specimens per unit area of substrate. In either physically or chemically stressed environments invertebrate communities are often sparsely populated; or densely populated by one particularly tolerant taxon.

Brillouin's diversity is a measure of balance; specifically, the numerical distribution between the members of an ecological community. Along with Shannon's diversity it is one of two diversity measures commonly used as ecological descriptors. Brillouin's diversity is calculated according to the formula:

$H = (\log N! - \text{sum} \log n_i!)/N$, where: N = the total of all individuals and,
n_i = the number of individuals in the ith species.

It is more the appropriate of the two for use in describing the diversity of invertebrate samples taken from the various locations in the Kin-Buc study area. This is because the samples are representative only of the particular locations from which they were drawn, and hence represent a "total" collection of invertebrate samples, rather than a "random" sample from a larger population. This problem stems from an absence of randomization in the study design used to collect the samples. Samples were obtained from fixed sites, with limited opportunity to incorporate spatial variation within a larger inference space (the zones) that samples ideally represent. The samples in this study do not statistically represent the nominal zones from which they are drawn. Because samples collected along transects are not random samples from an inference space, they are very likely spatially auto-correlated. Brillouin's index is the appropriate measure when the entire collection of invertebrate samples is represented. Since there is no way to know what specifically the larger area of space being represented is, the data are best treated as being applicable to the smaller area (the transects) sampled, and hence Brillouin's index is used.

Healthy communities are usually diverse. Brillouin's diversity can vary according to how invertebrate samples are processed. However, for this data set, values near 1.50 (in base e) are interpreted as intermediate.

Evenness (also referred to as equitability) is a related measure of community balance that is the ratio between the actual diversity calculated versus the maximum diversity obtainable from particular sample data (relative diversity). Evenness measures are calculated because there is no way of knowing, on the basis of the diversity index alone, which of the two components of diversity (first, the number of species or second, the relative distribution of the number of individuals in the ith species times the number of species) is responsible for the difference between index values. Therefore the two measures used together convey more information about "diversity" than either single measure alone. Results range from 0.00 and 1.00, and results close to 1.00 indicate optimal distribution.

To conduct the trend analysis, four of the metrics were graphed. Each graph is specific for one transect-pair (zone) and illustrates temporal trends for richness, density, percent contribution of the dominant taxon, and Brillouin's diversity.

The fisheries data were collected qualitatively. Hence, these data were evaluated primarily using richness (the number of species) and the percentage of individuals captured from each species as descriptors.

7.2 Results and Discussion

Invertebrate results from Edmonds Creek are organized beginning with the most upstream zone, and progress downstream towards the confluence of Edmonds Creek with the Raritan River (Tables 6 and 7a through 7g). Results from the two reference zones are presented in an upstream direction (Tables 6, 7h, and 7i). Fisheries data collected from Edmonds and Reference Creeks are presented as Tables 8a and 8b, respectively.

The graphs illustrating five-year trends in the ecological metrics calculated for the invertebrate data are given as Figures 48 through 56. Due to software limitations, no more than two of the four metric scales could be displayed simultaneously on the vertical axes of each figure. Therefore, in order to present all four metrics on one graph, two of the scales are modified. Mean densities are shown in units of 100 (e.g., an average density of 2,536 per square meter would be placed slightly above the number 25 along the left vertical axis). The scale that represents Brillouin's diversity was multiplied by 100 (e.g., an average diversity value of 0.44 would be placed slightly above the number 40 along the right vertical axis). The scales for richness (total taxa) on the left axis and percent contribution of the dominant taxon on the right axis correspond to the actual values calculated. Actual values are provided on each figure and the identity of the dominant taxon each year is also given.

Laboratory and Field Data Sheets are provided in Appendices D (fish) and E (invertebrates).

Quality Control

Quality Control was conducted during the sorting effort by re-sorting the matrices for three of the benthos samples. Quality Control was considered acceptable if greater than 90.0 percent of both taxa and specimens were removed during the initial effort. These results are shown as follows:

Sample	Taxa Removal (Percent)	Specimen Removal (Percent)
UN-ABEN-02S	100.0	96.0
UN-ABEN-02AS	100.0	98.2
A-33+00S	100.0	96.8

Taxa and specimen removal efficiency were acceptable.

Quality Control was conducted during the identification phase of the invertebrate analysis through independent re-identification of six samples (A11+00S, UN-ABEN-02AVL, A33+00IR, A52+50VL, UN-ABEN-01LS, and UN-ABEN-01AIR) by a second biologist. Where identifications differed, the criteria each biologist used to identify particular taxa were reviewed. A final determination was made for taxa in question at by placing the specimen(s) at the lowest taxonomic level that could be confirmed. This process resulted in three amendments to the original data set.

Identifications of the fish species collected during the seining effort were confirmed through verification of voucher specimens returned to the laboratory.

Water Quality

Results of the water quality measurements made during the invertebrate sampling effort are reported below. Results of the water quality measurements made during the seining effort were reported previously in Section 6.2.2.

Edmonds Creek Zones	Transect	Water Temp. (C)	Dissolved Oxygen (mg/l)	pH (std. units)	Salinity (ppt)	Conductivity (µmhos/cm)
Remediated Zone 1	A11+00	20.0	7.5	6.7	6.0	9,600
	A12+50	22.5	4.6	7.1	4.5	7,150
Remediated Zone 2	A20+62	23.0	4.5	7.0	6.0	9,400
	A22+50	23.0	4.2	7.0	7.0	11,800
Unremediated Zone 2	ABEN-02	23.0	4.2	7.1	12.0	17,950
	ABEN-02A	23.0	4.3	7.0	13.5	20,150
Remediated Zone 3	A31+00	24.5	5.3	7.1	13.5	20,600
	A33+00	23.0	4.6	7.3	16.5	22,800
Remediated Zone 4	A42+25	23.5	4.6	7.2	14.0	22,050
	A46+50	23.5	4.6	7.2	10.5	16,00
Remediated Zone 5	A50+50	23.5	4.4	7.1	9.5	14,800
	A52+50	22.5	4.5	7.0	9.0	9,350
Unremediated Zone 1	ABEN-01	22.5	4.8	7.2	13.5	20,200
	ABEN-01A	22.5	5.0	6.9	12.5	18,900
Reference Creek Zones						
Reference Zone 1	ABEN-01	23.0	4.9	7.0	14.0	22,050
	ABEN-01A	22.0	4.7	6.9	14.5	22,200
Reference Zone 2	ABEN-02	22.5	4.6	6.9	12.5	19,750
	ABEN-02A	22.5	4.7	7.1	13.5	20,100

These results show water quality to be similar in each stream. Dissolved oxygen concentrations were consistently low and appeared to be exacerbated by drought conditions. Soft mucky substrates, typical of tidal marsh systems, were observed throughout the study area. These are often anoxic; a condition that restricts the number and types of invertebrates and demersal fish that can colonize them. The field measurements indicated that Edmonds and Reference Creeks are warm-water streams characterized by fluctuating oxygen levels and salinity; also limiting factors. Given this template of ecological constraints, limited invertebrate and fish communities, consisting of taxa adapted to a range of physical and chemical conditions, would be expected.

Benthic Macroinvertebrates

During 1999, a cumulative total of 22 invertebrate taxa was collected from the two streams. The average number of taxa identified from particular zones was 8 per zone from Edmonds Creek and 7 per zone from Reference Creek. Thus, taxonomically poor communities were observed from both streams. Invertebrate density at Edmonds Creek indicated a sparse community and averaged 274 per square meter (all samples combined). Community density was even lower in Reference Creek, averaging 42 per square meter. Two taxa, an estuarine worm named *Neanthes succinea* or a crustacean named *Cyathura polita*, were the dominant taxa in each stream. Both are brackish water forms that represented from 38.6 to 66.8 percent of all specimens collected from particular zones. A tubeworm in the taxon *Limnodrilus sp.* (a fresh water form) was common at a single transect located at the upstream terminus of the Edmonds Creek study area. *Limnodrilus* sp. represented 45.3 percent of the total number of specimens collected at Transect A11+00 VR/IR/S (all were collected from sub-tidal habitats).

In addition to the invertebrate taxa identified from the quantitative effort, four additional taxa, too large to be easily captured with a Petit Ponar, were commonly observed in both streams during the seining effort. The blue crab (*Callinectes sapidus*) and the grass shrimp (*Palaemonetes pugio*) were found to be abundant at both Edmonds and Reference Creeks. Their presence at specific zones is noted on the Fish Data Sheets provided in Appendix D. Also very common was the brackish water fiddler crab, the target organism for the PCB analysis (see Photograph No. 7, Figure 1), and the acorn barnacle (*Balanus* sp.), observed attached to driftwood.

Fish

In 1999 only 10 species of fish were collected from the two streams, 6 among 1,527 specimens captured at Edmonds Creek and 8 among 749 specimens captured at Reference Creek. The large numbers of fish captured show robust communities in both streams. During the five year monitoring effort the number of species captured from Edmonds Creek averaged 8 per year and ranged between 4 and 15 in particular years. Similarly, the number of species captured from Reference Creek averaged 9 per year and ranged annually from 6 to 12. The number of fish captured from Edmonds Creek averaged 1,429 per year and the number of fish captured from Reference Creek averaged 1,003 per year, indicating robust communities each year.

Mummichog, a hardy species resistant to oxygen depletion (a typical adaptation to marsh life), was by far most common fish present in Edmonds Creek in 1999 comprising 72.7 percent of the catch. Mummichogs were the most commonly collected fish in Edmonds Creek each year. Mummichogs are in the killifish family, grow to a size of approximately six inches, and are abundant in coastal waters. They are found among growths of aquatic vegetation in streams with muddy bottoms. In the winter they are known to burrow into the mud to hibernate. In the spring, mummichogs migrate from brackish to fresher water to spawn. They are an omnivorous species with a varied diet consisting of algae, detritus, worms, crustaceans, mollusks, and smaller fish.

Atlantic silversides (*Menidia menidia*) were second in abundance (24.8 percent) in 1999 and were also common in Edmonds Creek during all prior years. Atlantic silversides are an abundant schooling fish found in estuaries that migrate into tidal streams. They prefer sandy bottoms. They are a small species seldom growing to a length over three and one-half inch, which feeds upon small worms and crustaceans. Silversides spawn in shallow water in the spring. Eggs are attached to aquatic vegetation.

Atlantic Menhaden (*Brevoortia tyrannus*), common carp (*Cyprinus carpio*), white perch (*Morone americana*) and American sole (*Trinectes maculatus*) were the other species collected in 1999.

A total of 21 fish species have been captured from Edmonds Creek since the remediation.

In 1999, mummichogs were uncharacteristically scarce in Reference Creek where, Atlantic menhaden was the most common fish collected (47.8 percent), followed by Atlantic silversides (40.1 percent). Mummichogs ranked a distant third (5.1 percent). Prior to 1999 Mummichogs and Atlantic silversides were co-dominants in Reference Creek, and menhaden were collected in smaller numbers. Atlantic menhaden, a herring, reaches a length of eighteen inches. Menhaden are an ocean fish whose young utilize brackish tidal streams as a nursery area. They occur in dense schools but are sensitive to oxygen depletion. Their population densities are believed to be cyclical.

Additional species collected in 1999 were bay anchovy (*Anchoa mitchilli*), white perch, common jack (*Caranx hippos*), bluefish (*Pomatomus saltathrix),* and naked goby (*Gobiosoma sp.*).

Since 1995, 16 species have been collected from Reference Creek. Hence, community richness in Edmonds Creek slightly exceeded that in Reference Creek.

Two other fish species were encountered in high numbers in particular years. Bay anchovy were abundant one year in Reference Creek (32.0 percent of the total in 1995) and juvenile white perch were common one year in Edmonds Creek (12.4 percent in 1996). Bay anchovy is a very abundant species found at salinities as low as 0.5 ppt. It is a small schooling species that reaches a length of two to three and one-half inch and feeds upon small crustaceans and zooplankton. They are often encountered in shallow muddy coves and streams in the summer, but migrate to deep water during cold weather. Anchovies have a protracted spawning season extending from May through October. Their eggs are pelagic. White perch is a common temperate bass that attains a length of eleven inches by feeding upon small fish, crustaceans, and worms. It is essentially an anadromous species that spawns during April and May. White perch are found in a variety of brackish to fresh water habitats and have the capacity to form resident populations wherever they occur.

Relative abundance among the fish profiled above (mummichog, Atlantic silverside, Atlantic menhaden, bay anchovy, and white perch) fluctuated from year to year. However, the assemblage formed by these five species represented from 95 to 100 percent of the collective totals each year from both streams, indicating a high degree of similarity. More importantly, annual fluctuations occurred to a greater extent at Reference Creek. For example, the annual relative abundance for mummichogs at Reference Creek was 55.6 (1995), 15.2 (1996), 45.3 (1997), 80.9 (1998), and 5.1 (1999) percent. More consistent results were obtained from Edmonds Creek where mummichogs represented 96.9 percent of the sample total in 1995 and from 64.5 (1996) to 92.1 (1998) percent thereafter. Therefore, the Edmonds Creek community was much more stable from year to year.

It appeared that the fish community in Edmonds Creek recovered from the remedial excavation rather quickly, around 1996 or 1997, when the greatest numbers of species were captured.

7.2.1 Edmonds Creek Macroinvertebrate Community

Upstream Zones -1999

Remediated Zones 1 and 2 are located at the upstream end of the study area (see Drawing 1.0). The substrates within these zones were characterized as brown silt, brown-gray silt, or dark gray silt (see Grain Size Distributions in Appendix A). Flecks of oil were occasionally noted on the water surface. Oil flecks were observed on the water surface throughout much of Edmonds Creek and Reference Creek, and were most obvious during tide changes when transported by the current. The source of the oil is unknown but appears to be non-point. In addition to residual PCBs, high percentages of organic carbon in the sediment samples made it appear that decomposition may also be a contributing factor.

The invertebrates collected at the upstream zones in 1999 and the metrics calculated from the data are listed on Table 6 and Tables 7a and 7b. Taxonomic richness was fairly low averaging 8 taxa per zone. Community density averaged 366 individuals per square meter. Aquatic worms within the genus *Limnodrilus* were the dominant invertebrate collected at the most upstream transect (11+00VR/IR/S) but were replaced by *Neanthes succinea* at Transect 12+50 VR/IR/S, a short distance downstream, and at Remediated Zone 2.

Limnodrilus, also referred to as tube worms, are a ubiquitous fresh-water burrowing form that is able to tolerate slightly saline conditions. The large number of tubificids at the most upstream transect indicate rather pronounced oxygen depletion within the Edmonds Creek sediments. They are able to withstand complete absence of oxygen for extended periods and are often the dominant invertebrate found in habitats that are subject to strong diurnal fluctuations. Ecologically, *Limnodrilus* occupy the same ecological niche as terrestrial earthworms. They feed on the bottom mud and mix it in the same manner. Food is typically ingested just below the benthic water-substrate surface where colonization by more oxygen dependant forms is difficult.

Neanthes succinea is a predatory euryhaline (adapted to a range of salinities) species that is common on muddy substrates. Referred to in the literature as clamworms or sandworms, they are a burrowing/tube making form but are also fairly mobile because they have the capacity to swim. They occasionally occur in fresh water but prefer higher salinity than does *Limnodrilus*. Thus, a longitudinal salinity gradient in Edmonds Creek likely acts as a partitioning mechanism between the two taxa.

In 1999 Brillouin's diversity values were 1.10 and 0.89, and evenness values were 0.68 and 0.52 at the two zones. These values are considered to be low due to the dominance of *Limnodrilus* and *Neanthes succinea*. Invertebrate communities dominated by tolerant forms are commonly observed in ecosystems where living conditions are difficult. These results may be considered typical of soft anoxic marsh sediments with tidal salinity fluctuations.

Five Year Trend

Yearly changes in the ecological metrics indicated a gradual improvement in biotic integrity from 1995 to 1998 (Figures 48 and 49). Increases in richness were accompanied by corresponding decreases in percent contribution of the dominant taxon. Diversity also improved considerably through 1998.

Although *L. hoffmeisteri* were dominant through 1998, their percent contribution dropped from 86.0 percent in 1995 to 60.0 percent in 1998 at Zone 1 and from 84.6 percent in 1995 to 26.0 percent in 1998 at Zone 2. Only one other taxon was dominant at either zone during the first four years of monitoring. In 1997 a fresh-water midge, *Chironomus*, was the dominant at Zone 2, representing 37.4 percent of the total. Chironomus is a second burrowing form, resistant to oxygen depletion. They are included in a group of midges referred to as the "blood-red" chironomids due to the presence of hemoglobin-like compound in their circulatory system called erythrocruorin that acts as a respiratory pigment. *Chironomus* also have two pairs of respiratory gills on the back of their abdomen that further aid oxygen metabolism.

In 1999 the invertebrate community showed a clear response to a long (record) period of drought that almost certainly created (on average) a more saline environment in this (upstream) section of Edmonds Creek than was the case during prior years. From 1995 to 1998 *Limnodrilus* were typically a dominant taxon as far downstream as Remediated Zone 3. In 1999 the more saline form *Neanthes succinea* was favored, and increased its' range upstream nearly to the end of the study area.

The results from the invertebrate collections made during the initial four years of monitoring also showed a longitudinal shift in community composition towards saline forms. However, prior to 1999, this shift (first seen during 1997 from the Unremediated Zone 2 data) happened much further downstream, and corresponded to a change in the flow character of Edmonds Creek that was observed at low tide. At low tide the more upstream zones were drained to the extent that surface flow from the surrounding landscape became visible as gravity fed non-tidal current. Once locations as far downstream as Zone 4 were reached, all visible current was tidal, regardless of tide stage. This change in flow character appeared to have contributed to the shift in community structure.

The 1999 observations are noteworthy because they show an invertebrate community that is being regulated by climatic variables rather than by physical disruptions to the benthic environment, attributable to the excavation of contaminated sediments. Thus, it is reasonable to conclude that the re-establishment of the macroinvertebrate community within the upstream portion of the Edmonds Creek study area is now complete.

Midstream Zones - 1999

Unremediated Zone 2 and Remediated Zones 3 and 4 are located within the mid-reach of the study area. There, substrates were characterized as brown silt, brown-gray silt, brown and gray silty sand, brown sandy silt, or dark gray silt with sand. The greatest amount of sand was present in the center of the channel in Unremediated Zone 2. Flecks of oil were observed on the water surface at Unremediated Zone 2. An oily rust colored substrate was noted from a tributary where Transect A31+00VL/IL/S is located.

The invertebrates collected from the mid-reach of Edmonds Creek in 1999 are listed on Table 6 and Tables 7c, 7d, and 7e. Taxonomic richness remained low and averaged 8 taxa per zone. Community density, also low, averaged 291 per square meter per zone. Two brackish forms were the dominants. *Neanthes succinea* ranked first in abundance at Unremediated Zone 2 and Remediated Zone 3, followed by a crustacean named *Cyathura polita*. *Cyathura polita* became dominant at Remediated Zone 4, where *Neanthes Succinea* ranked second.

Cyathura polita, commonly referred to as the slender isopod, is a wide-ranging euryhaline species found in nearly all tidal habitats. It is characteristically found associated with salt-marsh grass (*Spartina*) and has also colonized the vast growths of fragmite (*Fragmites*) found in Edmonds Creek. Historically, they have been most abundant in the mid and downstream sections of the Edmonds Creek study area where salinity is generally higher. *Cyathura* is a tube-making invertebrate that prefers hard substrates. It is primarily a detritus-algal feeder and also scavenges.

In 1999 Brillouin's diversity values were low, 0.84, 0.84, and 1.10, at the three zones. Evenness was fairly low, calculated at 0.60, 0.72, and 0.55 within particular zones. These results were consistent with diversity and evenness results obtained from the upstream section of the study area.

Five Year Trend

During 1995 to 1998 most of the metric results from the mid-reach indicated an improvement in biotic integrity. Improved biotic integrity was illustrated by increases in richness and diversity, and by decreases in percent contribution of the dominant, within all three zones (Figures 50 through 52). *Limnodrilus* and *Cyathura polita* were most frequently the dominant taxon during successive years through 1998 in all zones. Two other taxa, *Hypaniola grayi* (1997) and nr. *Enchytraeus sp.* (1998), were dominant in particular years at Unremediated Zone 2. During 1995 to 1998 the percent abundance of the dominant taxon decreased within all three zones: from 86.6 to 27.8 percent at Unremediated Zone 1; from 60.6 to 29.9 percent at Remediated Zone 2; and from 37.5 to 22.4 percent at Remediated Zone 4.

Hypaniola grayi is a tube-building form commonly referred to as an ampharetid worm. Ampharetids are deposit-feeders in mud or sand that collect particulate matter with a set of tentacles. Most ampharetids are found in deep water, but *Hypaniola grayi* is euryhaline and adapts to a variety of estuarine environments. *Enchytraeus* is a cosmopolitan tube-worm phylogenetically and behaviorally similar to *Limnodrilus*. Many species within the genus are semi-aquatic; and most of the individuals that have been found in Edmonds Creek were identified from samples collected from inter-tidal habitats. Ecologically they are burrowers in mud and detritus, and are resistant to both oxygen depletion and fluctuations in salinity.

In 1999 the invertebrate community in the middle section also responded negatively to drought conditions. In addition to the shift in dominance towards *Neanthes succinea* at Unremediated Zone 2 and Remediated Zone 3, the metric results changed in a similar fashion to those obtained from the upstream section. Reductions in richness and diversity were accompanied by increases in percent contribution of the dominant taxon in all three zones.

It appears that invertebrate re-colonization of the mid-reach sediments is now complete and the community is being regulated by climatic variables.

Downstream Zones - 1999

The downstream section of Edmonds Creek includes Remediated Zone 5 and Unremediated Zone 1. Sediments there were described as brown silt, brown-gray silt, brown and gray silt, brown and dark gray silt, or brown and gray silt with sand. Flecks of oil were observed on the water surface at Unremediated Zone 1.

The data and metrics obtained downstream during 1999 are given as Tables 6, 7f, and 7g. Richness continued to be low as 8 taxa were identified from each zone. Community density was also low, averaging 174 per square meter. *Cyathura polita* was the dominant at each zone where it represented 57.0 and 61.9 percent of the sample totals. Diversity and evenness values were low and consistent with values calculated further upstream. Diversity indices were 1.28 and 0.96 and evenness values were 0.74 and 0.62.

Five Year Trend

The trends produced from five years of monitoring at the downstream zones are presented on Figures 53 and 54.

At Remediated Zone 5 the metrics remained fairly consistent from year to year. Slight reductions in richness and density were observed in 1999, but the percent contribution of the dominant taxon and Brillouin's diversity remained within previously established ranges. *Cyathura polita* was the dominant during three of the five years. *Limnodrilus* (1995) or *Hypaniola grayi* (1998) were dominant one year each.

Near the mouth of Edmonds Creek, at Unremediated Zone 1, the metrics tended to fluctuate from year to year; and then showed a decline in biotic integrity in 1999. In 1999 the metrics pertaining to richness, density, and diversity were all the lowest observed during the five-year period, and percent contribution of the dominant was high. Thus, the 1999 data produced a similar pattern to that seen at the majority of the zones upstream. Cyathura polita was the dominant from 1997 to 1999. *Limnodrilus* (1995) or a crustacean, *Gammarus* (1996), were dominant one year each.

Gammarus, commonly referred to as sideswimmers, are common omnivores found in brackish and fresh environments; and species distribution is partially segregated by salinity gradients. *Gammarus* is essentially a benthic genus that occurs in debris and on driftwood in the upper portions of estuaries, at salinities of 1 to 25 ppt. They are occasionally abundant near creek mouths and sensitive to oxygen depletion. Their presence at as a dominant at Unremediated Zone 1 in 1996 may be due to the proximity of the zone to the Raritan River.

Annual variation at the downstream zones made identification of the specific year the benthic community recolonized there difficult. However, the community did respond to drought in an analogous fashion to the communities further upstream. Re-colonization appears to be complete and recent shifts in the invertebrate metrics are due to natural variability, exacerbated by climatic stress.

Summary

The results presented above are representative of a benthic habitat consisting of soft unstable mostly muddy substrate (probably anoxic), at all of the zones. Oxygen concentrations in the water column were less than optimal but suitable for the reestablishment of a viable invertebrate community. Salinity values fluctuated with the tides and appeared to be lower at the two most upstream zones. There was a pronounced shift in community composition between upstream and downstream zones where a freshwater form, *Limnodrilus hoffmeisteri* was replaced as the dominant taxon by forms associated with more saline environments. Until 1999, this shift corresponded to the change in the physical nature of Edmonds Creek from a stream subject to gravity fed surface flow, during low tide upstream, to one where flow was exclusively tidal downstream. During 1999, the change occurred further upstream in response to severe drought conditions.

Temporal shifts in community metrics were one directional at transects upstream from, adjacent to, and immediately downstream from OU2, indicating a general trend towards improved biotic integrity through 1998. The improvement was mostly illustrated by trends of increasing taxonomic richness and community diversity, and corresponding decreases in percent contribution of the dominant taxon.

The invertebrate data revealed a community dominated by tolerant taxa. In general, the data reveal a viable but somewhat repressed community in Edmonds Creek; and that re-colonization of the study area is complete.

7.2.2 Reference Creek Macroinvertebrate Community

1999

The sediments at Reference Zones 1 and 2, near the confluence of Reference Creek with the Raritan, were predominantly, brown silt, brown-gray silt, or dark gray silt. They were quite similar in appearance to the sediments at Edmonds Creek. Flecks of oil were observed on the water surface.

Taxonomic composition resembled that from the two most downstream zones in Edmonds Creek (Tables 6, 7h, and 7i) as brackish water forms were most frequently collected. However, taxonomic richness and density were lower. An average of 6 taxa was collected per zone, at a noticeably sparse mean density of 42 individuals per square meter. *Cyathura polita* and *Neanthes succinea* were the dominants within particular zones.

Average diversity values were low. Diversity indices were 1.26 and 0.70. Evenness values were high, 0.76 and 0.82. However, the evenness values should be interpreted with caution because they were derived from sample data that consisted of very few specimens. Only 13 specimens were present in the samples from Reference Zone 1 and only 6 were present in samples from Reference Zone 2. The evenness values were high because the two dominants were present in similar numbers.

Five Year Trend

The trend towards improved biotic integrity seen from Edmonds Creek from 1995 to 1998 was not repeated at Reference Creek (Figures 55 and 56). During the first four years of monitoring at Reference Creek the metrics describing richness and density remained fairly constant from year to year at both zones. Percent contribution of the dominant taxon increased over time at Zone 1 and tended to fluctuate at Zone 2. All taxa dominant at Edmonds Creek were usually dominant at Reference Creek. In addition, a second euryhaline worm, *Marenzelleria viridis* (1996) and a second pollution tolerant midge in the genus *Procladius* (also in 1996), were dominants at Zones 1 and 2, respectively. Diversity trended downward over time at Zone 1 and fluctuated at Zone 2. Thus, through 1998 the metric calculations suggested a slight decrease in biotic integrity at Zone 1 and essentially a stable community at Zone 2.

The drought response described from the 1999 Edmonds Creek data was observed from one of the two reference zones. Although the metrics derived from Zone 1 continued to fluctuate through 1999, distinct reductions for richness, density, and diversity were observed at Zone 2. In addition, percent contribution of the dominant was relatively high.

Summary

A comparison of the invertebrate data and metric calculations between Reference Creek and Edmonds Creek indicated somewhat dissimilar communities. Taxonomic composition was similar in both streams, but community density was considerably lower in Reference Creek. In addition, annual changes in the identity of the most common taxon were more noticeable in Reference Creek.

The downstream shift in community structure seen in the Edmonds Creek system was not repeated in Reference Creek, likely because all transects in Reference Creek were located near the mouth of the stream. In addition, the change in flow (low tide) characteristics described from Edmonds Creek, as the transect locations progressed downstream, did not occur at the Reference Creek. At Reference Creek, flow at low tide was the result of gravity fed surface flow all the way to the mouth of the stream. Flow within the entire length of the study area then became tidal at mid and high tides.

The 1995 to 1999 trends in community metrics, observed at the two reference zones, were most similar to trends described from the two downstream zones at Edmonds Creek. These trends revealed a relatively large degree of annual variation, and in one of two instances showed a disturbance response related to drought. Because positive trends seen over most of the length of the Edmonds Creek through 1998 were matched by either neutral or negative trends at Reference Creek, the metric data suggest that, at a broader scale, the separate communities were responding to a different set of environmental variables. It appeared that through 1998 the Edmonds Creek community was in a state of recovery from the physical disturbance caused by the remedial excavation while the Reference Creek community was in a normal state. In 1999, both communities responded similarly to the climatic disturbance caused by extensive drought.

Table 6. Ecological Metrics for the Kin-Buc Landfill Macroinvertebrate Results from 1999 (year 5).

Zones	Total taxa	Average density (no./sq.m)	Percent contribution dominant taxon		Average Brillouin's Diversity	Average Brillouin's Evenness
<u>Edmonds Creek</u>						
Rem 1	9	308	*Neanthes succinea*	- 38.6%	1.10	0.68
Rem 2	8	421	*Neanthes succinea*	- 66.8%	0.89	0.52
Unrem 2	7	500	*Neanthes succinea*	- 60.9%	0.84	0.60
Rem 3	9	246	*Neanthes succinea*	- 42.3%	0.84	0.72
Rem 4	9	128	*Cyathura polita*	- 62.1%	1.10	0.55
Rem 5	8	204	*Cyathura polita*	- 57.0%	1.28	0.74
Unrem 1	8	114	*Cyathura polita*	- 61.9%	0.96	0.62
<u>Reference Creek</u>						
Ref 1	10	65	*Cyathura polita*	- 52.3%	1.26	0.76
Ref 2	4	18	*Neanthes succinea*	- 58.8%	0.70	0.82

Table 7a. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Remediated Zone 1**
Sample Date: August 31, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect 11+00 VR/IR/S Veg.	Int.	Sub.	Mean (no./sq.m.)	Pct.	Transect 12+50 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Tubificida											
poss. *Enchytraeus sp.*	tube worm			11	53	17.2					
Limnodrilus sp.	tube worm			29	140	45.3					
Phyllodocida											
Neanthes succinea	clam worm		1	8	43	14.1			41	198	63.1
Terebellida											
Hypaniola grayi	ampharetid worm	1	1	1	14	4.7					
Decapoda											
Palaeomenetes pugio	grass shrimp	1			5	1.6					
Isopoda											
Cyathura polita	slender isopod	8	1		43	14.1	22	1		111	35.4
Diptera											
Ceratopogon sp.	biting midge			1	5	1.6					
Chironomus sp.	midge								1	5	1.5
Chrysops sp.	deer fly	1			5	1.6					
Taxa per sample		4	3	5		100.0	1	1	2		100.0
Density per sample (no./sq.m.)		159	43	725			319	14	609		
Total taxa per transect					8					3	
Mean density per transect (std. error)					308	(211)				314	(172)
Dominant taxon by transect					*Limnodrilus sp.*					*Neanthes succinea*	
Percent dominant taxon by transect					45.3%					63.1%	
Brillouins diversity by transect					1.50					0.71	
Brillouins evenness by transect					0.72					0.64	

Total taxa per zone	9	
Mean density per zone (std. error)	311	(122)
Dominant taxon by zone	***Neanthes succinea***	
Percent dominant taxon by zone	**38.6%**	
Brillouins diversity by zone	**1.10**	
Brillouins evenness by zone	**0.68**	

Water Chemistry Data:	Transect 11+00	Transect 12+50
Secci: water clarity (ft)	0.8	0.7
Water temperature (C)	20.0	22.5
Dissolved oxygen (ppm)	7.5	4.6
pH (standard units)	6.7	7.1
Salinity (ppt)	6.0	4.5
Conductivity (umhos/cm)	9600	7150

Table 7b. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Remediataed Zone 2**
Sample Date: August 31, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect 20+62VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect 22+50 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Phyllodocida											
Neanthes succinea	clam worm	1	15	27	208	84.4	3	12	58	353	59.4
Terebellida											
Hypaniola grayi	ampharetid worm								1	5	0.8
Decapoda											
Uca minax	fiddler crab						2			10	1.6
Isopoda											
Cyathura polita	slender isopod		2	2	19	7.9	13	3	4	97	16.3
Diptera											
Ceratopogon sp.	biting midge			2	10	3.9		1	11	58	9.8
Chironomus sp.	midge			1	5	2.0					
Chrysops sp.	deer fly						15			72	12.2
near. *Raphium sp.*	long-legged fly	1			5	2.0					
Taxa per sample		2	2	4		100.0	4	3	4		100.0
Density per sample (no./sq.m.)		29	246	464			478	232	1072		
Total taxa per transect					5					6	
Mean density per transect (std. error)					247	(126)				595	(249)
Dominant taxon by transect					*Neanthes succinea*					*Neanthes succinea*	
Percent dominant taxon by transect					84.4%					59.4%	
Brillouins diversity by transect					0.60					1.18	
Brillouins evenness by transect					0.38					0.66	
Total taxa per zone							8				
Mean density per zone (std. error)							421	(147)			
Dominant taxon by zone							***Neanthes succinea***				
Percent dominant taxon by zone							**66.8%**				
Brillouins diversity by zone							**0.89**				
Brillouins evenness by zone							**0.52**				
Water Chemistry Data:											
Secci: water clarity (ft)					1.0					1.1	
Water temperature (C)					23.0					23.0	
Dissolved oxygen (ppm)					4.5					4.2	
pH (standard units)					7.0					7.0	
Salinity (ppt)					6.0					7.0	
Conductivity (μmhos/cm)					9400					11800	

Table 7c. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Unremediated Zone 2**
Sample Date: August 31, 1999
Gear: Petite Ponar Grab (0.023 m^2)

		Transect UN-BEN-02 VR/IR/S			Mean Density		Transect UN-BEN-02A VL/IL/S			Mean Density	
Taxon	Common Name	Veg.	Int.	Sub.	(no./sq.m.)	Pct.	Veg.	Int.	Sub.	(no./sq.m.)	Pct.
Phyllodocida											
Neanthes succinea	clam worm		2	36	184	59.4		8	80	425	61.5
Spionida											
Marenzelleria viridis	mud worm								1	5	0.7
Terebellida											
Hypaniola grayi	ampharetid worm	2		1	14	4.7		1	2	14	2.1
Amphipoda											
Orchestia grillus	beach flea						1			5	0.7
Decapoda											
Rhithropanopeus harrisii	mud crab						1			5	0.7
Isopoda											
Cyathura polita	slender isopod	7	2	14	111	36.0	1	18	29	232	33.6
Diptera											
near. *Raphium sp.*	long-legged fly						1			5	0.7
Taxa per sample		2	2	3		100.0	4	3	4		100.0
Density per sample (no./sq.m.)		130	58	739			58	391	1623		
Total taxa per transect					3					7	
Mean density per transect (std. error)					309	(216)				691	(475)
Dominant taxon by transect					*Neanthes succinea*					*Neanthes succinea*	
Percent dominant taxon by transect					59.4%					61.5%	
Brillouins diversity by transect					0.80					0.87	
Brillouins evenness by transect					0.74					0.45	
Total taxa per zone							7				
Mean density per zone (std. error)							500	(336)			
Dominant taxon by zone							***Neanthes succinea***				
Percent dominant taxon by zone							60.9%				
Brillouins diversity by zone							0.84				
Brillouins evenness by zone							0.60				
Water Chemistry Data:											
Secci: water clarity (ft)					1.0					0.9	
Water temperature (C)					23.0					23.0	
Dissolved oxygen (ppm)					4.2					4.3	
pH (standard units)					7.1					7.0	
Salinity (ppt)					12.0					13.5	
Conductivity ($u$mhos/cm)					17950					20150	

Table 7d. Macroinvertebrates collected from a Trib. to Edmonds Cr. and Edmonds Cr. near Kin-Buc Landfill, Middlesex Co, NJ.

Sample Zone: **Remediated Zone 3**
Sample Date: August 13, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect 31+00 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect 33+00 VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Tubificida											
Limnodrilus sp.	tube worm		1	1	10	28.5					
Phyllodocida											
Neanthes succinea	clam worm						2	14	27	208	45.3
Spionida											
Marenzelleria viridis	mud worm							1	4	24	5.3
Polydora ligni	mud worm								1	5	1.1
Terebellida											
Hypaniola grayi	ampharetid worm							1	3	19	4.2
Amphipoda											
Corophium lacustre	tube maker							1		5	1.1
Orchestia grillus	beach flea		5		24	71.5					
Decapoda											
Rhithropanopeus harrisii	mud crab							1		5	1.1
Isopoda											
Cyathura polita	slender isopod						4	12	24	193	42.1
Taxa per sample		0	2	1		100.0	2	6	5		100.0
Density per sample (no./sq.m.)		0	87	14			87	435	855		
Total taxa per transect					2					7	
Mean density per transect (std. error)					34	(27)				459	(222)
Dominant taxon by transect					*Orchestia grillus*					*Neanthes succinea*	
Percent dominant taxon by transect					71.5%					45.3%	
Brillouins diversity by transect					0.55					1.13	
Brillouins evenness by transect					0.87					0.58	

Total taxa per zone	9	
Mean density per zone (std. error)	246	(138)
Dominant taxon by zone	***Neanthes succinea***	
Percent dominant taxon by zone	42.3%	
Brillouins diversity by zone	0.84	
Brillouins evenness by zone	0.72	

Water Chemistry Data:	Transect 31+00		Transect 33+00
Secci: water clarity (ft)	1.0	(Trib.)	-
Water temperature (C)	24.5	(Trib.)	23.0
Dissolved oxygen (ppm)	5.3	(Trib.)	4.6
pH (standard units)	7.1	(Trib.)	7.3
Salinity (ppt)	13.5	(Trib.)	16.5
Conductivity (μmhos/cm)	20600	(Trib.)	22800

Table 7e. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Remediated Zone 4**
Sample Date: August 31, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect 42+25 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect 46+50 VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Heteronemertea											
Cerebratulus lactea	ribbon worm			1	5	3.3			1	5	4.4
Phyllodocida											
Neanthes succinea	clam worm		1	3	19	13.3		7		34	30.5
Spionida											
Marenzelleria viridis	mud worm			1	5	3.3					
Mytiloida											
Modiolus demissus	ribbed mussel						1			5	4.4
Amphipoda											
Gammarus sp.	sideswimmer						1			5	4.4
Orchestia grillus	beach flea	1			5	3.3	1			5	4.4
Decapoda											
Uca minax	fiddler crab	1			5	3.3					
Isopoda											
Cyathura polita	slender isopod	2	5	15	106	73.3		7	4	53	47.9
Diptera											
Ceratopogon sp.	biting midge							1		5	4.4
Taxa per sample		3	2	4		100.0	3	3	2		100.0
Density per sample (no./sq.m.)		58	87	290			43	217	72		
Total taxa per transect					6					7	
Mean density per transect (std. error)					145	(73)				112	(54)
Dominant taxon by transect					*Cyathura polita*					*Cyathura polita*	
Percent dominant taxon by transect					73.3%					47.9%	
Brillouins diversity by transect					0.90					1.31	
Brillouins evenness by transect					0.52					0.58	

Total taxa per zone	9
Mean density per zone (std. error)	128 (42)
Dominant taxon by zone	*Cyathura polita*
Percent dominant taxon by zone	62.1%
Brillouins diversity by zone	1.10
Brillouins evenness by zone	0.55

Water Chemistry Data:	Transect 42+25	Transect 46+50
Secci: water clarity (ft)	1.1	1.3
Water temperature (C)	23.5	23.5
Dissolved oxygen (ppm)	4.6	4.6
pH (standard units)	7.2	7.2
Salinity (ppt)	14.0	10.5
Conductivity (μmhos/cm)	22500	16000

Table 7f. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Remediated Zone 5**
Sample Date: August 31, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect 50+50 VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect 52+50 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Heteronemertea											
Cerebratulus lactea	ribbon worm	1	1	4	29	8.1		1		7	14.3
Capitellida											
Heteromastus filiformis	thread worm	1	3	1	24	6.8		2		14	28.5
Phyllodocida											
Eteone heteropoda	paddle worm							1		7	14.3
Neanthes succinea	clam worm		1	1	10	2.7		1		7	14.3
Spionida											
Marenzelleria viridis	mud worm		2		10	2.7					
Decapoda											
Uca minax	fiddler crab	2			10	2.7	1			7	14.3
Isopoda											
Cyathura polita	slender isopod	26	17	11	261	73.0		1		7	14.3
Diptera											
Chrysops sp.	deer fly	3			14	4.1					
Taxa per sample		5	5	4		100.0	1	5	-		100.0
Density per sample (no./sq.m.)		478	348	246			14	87	-		
Total taxa per transect					7					6	
Mean density per transect (std. error)					358	(67)				49	(37)
Dominant taxon by transect					*Cyathura polita*					*Heteromastus filiformis*	
Percent dominant taxon by transect					73.0%					28.5%	
Brillouins diversity by transect					1.00					1.57	
Brillouins evenness by transect					0.53					0.95	
Total taxa per zone						8					
Mean density per zone (std. error)						204	(84)				
Dominant taxon by zone						*Cyathura polita*					
Percent dominant taxon by zone						57.0%					
Brillouins diversity by zone						1.28					
Brillouins evenness by zone						0.74					
Water Chemistry Data:											
Secci: water clarity (ft)					0.7					0.8	
Water temperature (C)					23.5					22.5	
Dissolved oxygen (ppm)					4.4					4.5	
pH (standard units)					7.1					7.0	
Salinity (ppt)					9.5					9.0	
Conductivity (μmhos/cm)					14800					9350	

Table 7g. Macroinvertebrates collected from Edmonds Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Unremediated Zone 1**
Sample Date: September 1,1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect UN-BEN-01 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect UN-BEN-01A VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Heteronemertea											
Cerebratulus lactea	ribbon worm			2	10	5.3					
Capitellida											
Heteromastus filiformis	thread worm		3	1	19	10.5					
Phyllodocida											
Neanthes succinea	clam worm		1	1	10	5.3					
Spionida											
Marenzelleria viridis	mud worm			1	5	2.6					
Terebellida											
Hypaniola grayi	ampharetid worm		5	1	29	15.8					
Decapoda											
Rhithropanopeus harrisii	mud crab		1		5	2.6		1		5	11.1
Isopoda											
Cyathura polita	slender isopod		4	18	106	58.0		2	5	34	77.8
Diptera											
Ormosia sp.	crane fly						1			5	11.1
Taxa per sample		0	5	6		100.0	1	2	1		100.0
Density per sample (no./sq.m.)		0	203	348			14	43	72		

	UN-BEN-01		UN-BEN-01A	
Total taxa per transect	7		3	
Mean density per transect (std. error)	184	(106)	44	(17)
Dominant taxon by transect	*Cyathura polita*		*Cyathura polita*	
Percent dominant taxon by transect	58.0%		77.8%	
Brillouins diversity by transect	1.29		0.62	
Brillouins evenness by transect	0.68		0.57	

	Zone	
Total taxa per zone	8	
Mean density per zone (std. error)	114	(56)
Dominant taxon by zone	*Cyathura polita*	
Percent dominant taxon by zone	61.9%	
Brillouins diversity by zone	0.96	
Brillouins evenness by zone	0.62	

Water Chemistry Data:	UN-BEN-01	UN-BEN-01A
Secci: water clarity (ft)	1.3	1.2
Water temperature (C)	22.5	22.5
Dissolved oxygen (ppm)	4.8	5.0
pH (standard units)	7.2	6.9
Salinity (ppt)	13.5	12.5
Conductivity (μmhos/cm)	20200	18900

Table 7h. Macroinvertebrates collected from Reference Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Reference Zone 1**
Sample Date: September 1, 1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect RA-BEN-01 VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect RA-BEN-01A VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Phyllodocida											
Neanthes succinea	clam worm							3		14	21.4
Spionida											
Marenzelleria viridis	mud worm							1		5	7.1
Amphipoda											
Gammarus sp.	sideswimmer			2	10	15.3					
Melita nitida	sideswimmer			1	5	7.7					
Orchestia grillus	beach flea						1			5	7.2
Decapoda											
Rhithropanopeus harrisii	mud crab			1	5	7.7					
Uca minax	fiddler crab			1	5	7.7					
Isopoda											
Cyathura polita	slender isopod	3	4		34	54.0		5	2	34	50.1
Diptera											
Blaesoxipha sp.	flesh fly	1			5	7.7					
near. *Raphium sp.*	long-legged fly						2			10	14.2
Taxa per sample		2	1	4		100.0	2	3	1		100.0
Density per sample (no./sq.m.)		58	58	72			43	130	29		
Total taxa per transect					6					5	
Mean density per transect (std. error)					64	(5)				68	(32)
Dominant taxon by transect					*Cyathura polita*					*Cyathura polita*	
Percent dominant taxon by transect					54.0%					50.1%	
Brillouins diversity by transect					1.29					1.23	
Brillouins evenness by transect					0.73					0.78	

Total taxa per zone	10	
Mean density per zone (std. error)	65	(14)
Dominant taxon by zone	*Cyathura polita*	
Percent dominant taxon by zone	52.3%	
Brillouins diversity by zone	1.26	
Brillouins evenness by zone	0.76	

Water Chemistry Data:	RA-BEN-01	RA-BEN-01A
Secci: water clarity (ft)	1.5	1.0
Water temperature (C)	23.0	22.0
Dissolved oxygen (ppm)	4.9	4.7
pH (standard units)	7.0	6.9
Salinity (ppt)	14.0	14.5
Conductivity (umhos/cm)	22050	22200

Table 7i. Macroinvertebrates collected from Reference Creek near Kin-Buc Landfill, Middlesex County, New Jersey.

Sample Zone: **Reference Zone 2**
Sample Date: September 1,1999
Gear: Petite Ponar Grab (0.023 m^2)

Taxon	Common Name	Transect RA-BEN-02 VL/IL/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.	Transect RA-BEN-02A VR/IR/S Veg.	Int.	Sub.	Mean Density (no./sq.m.)	Pct.
Phyllodocida											
Neanthes succinea	clam worm		2		10	49.8		1	1	10	66.5
Spionida											
Marenzelleria viridis	mud worm		1		5	25.1					
Amphipoda											
Orchestia grillus	beach flea	1			5	25.1					
Isopoda											
Cyathura polita	slender isopod								1	5	33.5
Taxa per sample		1	2	0		100.0	0	1	2		100.0
Density per sample (no./sq.m.)		14	43	0			0	14	29		
Total taxa per transect					3					2	
Mean density per transect (std. error)					20	(13)				15	(8)
Dominant taxon by transect					*Neanthes succinea*					*Neanthes succinea*	
Percent dominant taxon by transect					49.8%					66.5%	
Brillouins diversity by transect					0.88					0.53	
Brillouins evenness by transect					0.83					0.82	

Zone summary		
Total taxa per zone	4	
Mean density per zone (std. error)	18	(15)
Dominant taxon by zone	*Neanthes succinea*	
Percent dominant taxon by zone	58.8%	
Brillouins diversity by zone	0.70	
Brillouins evenness by zone	0.82	

Water Chemistry Data:	RA-BEN-02	RA-BEN-02A
Secci: water clarity (ft)	0.9	1.1
Water temperature (C)	22.5	22.5
Dissolved oxygen (ppm)	4.6	4.7
pH (standard units)	6.9	7.1
Salinity (ppt)	12.5	13.5
Conductivity (μmhos/cm)	19750	20100

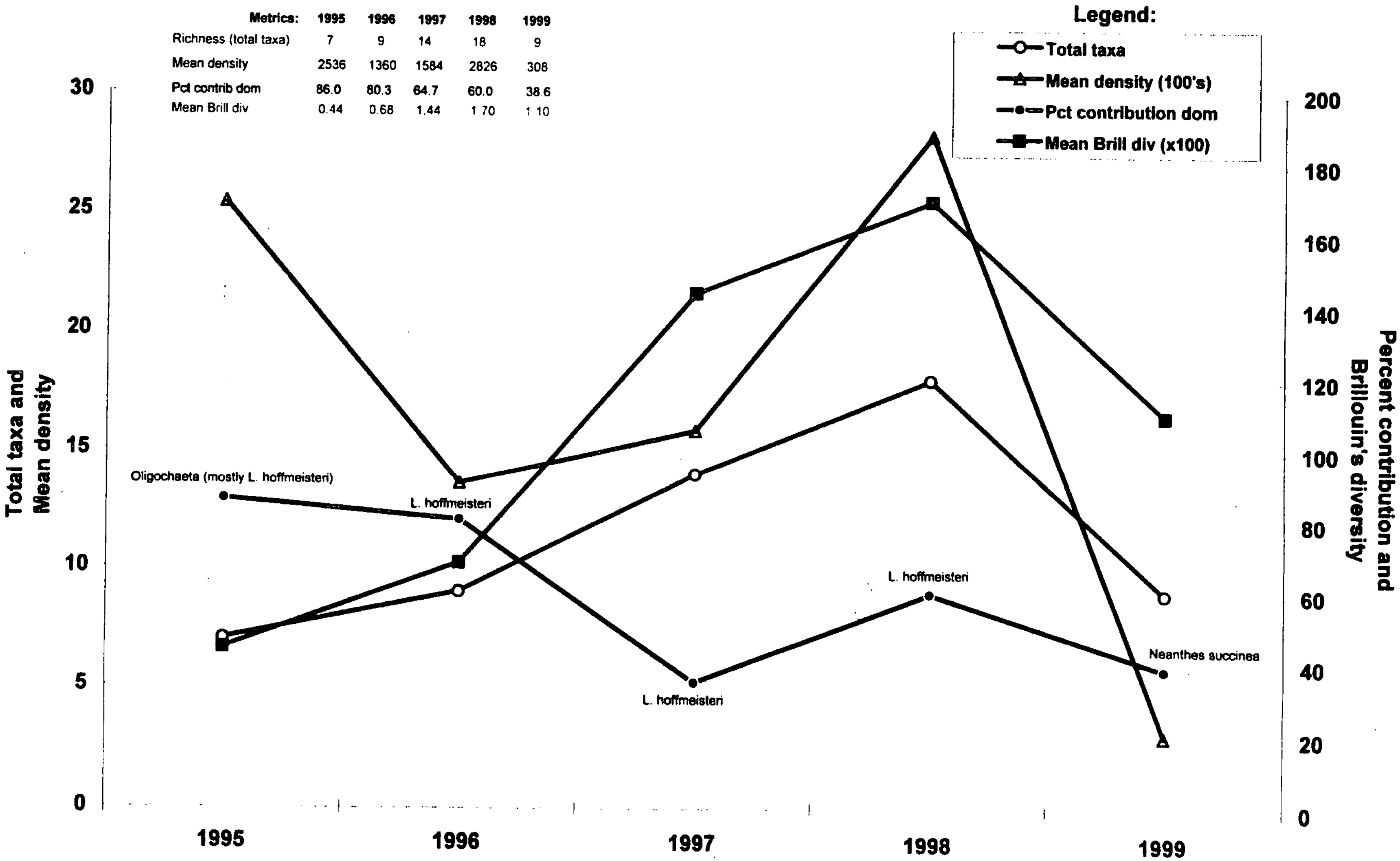
Table 8a. Fisheries data collected by seining from the Edmonds Creek Marsh near Kin-Buc Landfill during 1999 (year 5).

Scientific Name	Common Name	Edmonds Creek Zones								Total
		REM 1	REM 2	UN 3	UN 2	REM 3	REM 4	REM 5	UN 1	
Clupeidae										
Brevoortia tyrannus	Atlantic menhaden						25	1	5	31
Cyprinidae										
Cyprinus carpio	common carp		1							1
Cyprinodontidae										
Fundulus heteroclitus	mummichog	125	133	157	187	136	194	116	64	1,112
Atherinidae										
Menidia menidia	Atlantic silverside	3	21	1		56	14	112	172	379
Percichthyidae										
Morone americana	white perch					2		1	2	5
Soleidae										
Trinectes maculatus	American sole							1		1
	Total species	2	3	2	1	3	3	5	4	6
	Total fish	128	155	158	187	194	233	231	243	1,529
Water Chemistry Data:										
Water clarity: Secci (ft)		0.9	0.8	bot.	0.9	0.8	1.2	1.1	1.2	
Water temp (°C)		23.0	23.0	23.5	23.5	23.0	19.0	22.0	22.0	
Dissolved oxygen (mg/l)		4.6	4.5	4.8	4.8	4.8	5.2	5.1	4.7	
pH (std. units)		7.1	7.1	7.0	7.1	7.1	7.0	6.8	6.8	
Salinity (ppt)		8.0	8.0	8.0	8.5	9.0	5.5	5.5	5.5	
Conductivity (μmhos/cm)		12,100	12,100	12,700	12,300	12,500	7,900	8,400	8,800	

Table 8b. Fisheries data collected by seining from the Reference Creek Marsh near Kin-Buc Landfill during 1999 (year 5).

Scientific Name	Common Name	Reference Creek Zones RA 1	RA 2	RA 3	RA 4	RA 5	RA 6	RA 7	RA 8	Total
Clupeidae										
Brevoortia tyrannus	Atlantic menhaden	43	22	56	64	29	39	45	60	358
Engraulidae										
Anchoa mitchilli	bay anchovy		1		2	2	4	11		20
Cyprinodontidae										
Fundulus heteroclitus	mummichog	23	2	3	2				8	38
Atherinidae										
Menidia menidia	Atlantic silverside	50	33	56	55	48	26	22	10	300
Percichthyidae										
Morone americana	white perch	5	7	1	7	3	1			24
Carangidae										
Caranx hippos	common jack	1								1
Pomatomidae										
Pomatomus saltathrix	bluefish		4					1	2	7
Gobiidae										
Gobiosoma sp.	naked goby								1	1
	Total species	5	6	4	5	4	4	4	5	8
	Total fish	122	69	116	130	82	70	79	81	749
Water Chemistry Data:										
Water clarity: Secci (ft)		1.4	1.2	1.3	1.0	1.2	1.8	1.8	1.8	
Water temp (°C)		24.5	24.0	24.0	24.5	24.5	24.0	24.0	24.0	
Dissolved oxygen (mg/l)		6.6	5.5	5.2	4.6	5.1	5.8	5.8	5.7	
pH (std. units)		6.7	6.7	6.7	6.7	6.7	6.8	6.8	6.8	
Salinity (ppt)		7.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Conductivity (μmhos/cm)		11,000	8,000	8,000	8,000	8,050	8,000	8,000	8,000	

Figure 48. Five year trend in invertebrate community metrics derived from Remediated Zone 1 near Kin-Buc Landfill.



Metrics:	1995	1996	1997	1998	1999
Richness (total taxa)	7	9	14	18	9
Mean density	2536	1360	1584	2826	308
Pct contrib dom	86.0	80.3	64.7	60.0	38.6
Mean Brill div	0.44	0.68	1.44	1.70	1.10

Figure 50. Five year trend in invertebrate community metrics derived from Unremediated Zone 2 near Kin-Buc Landfill.

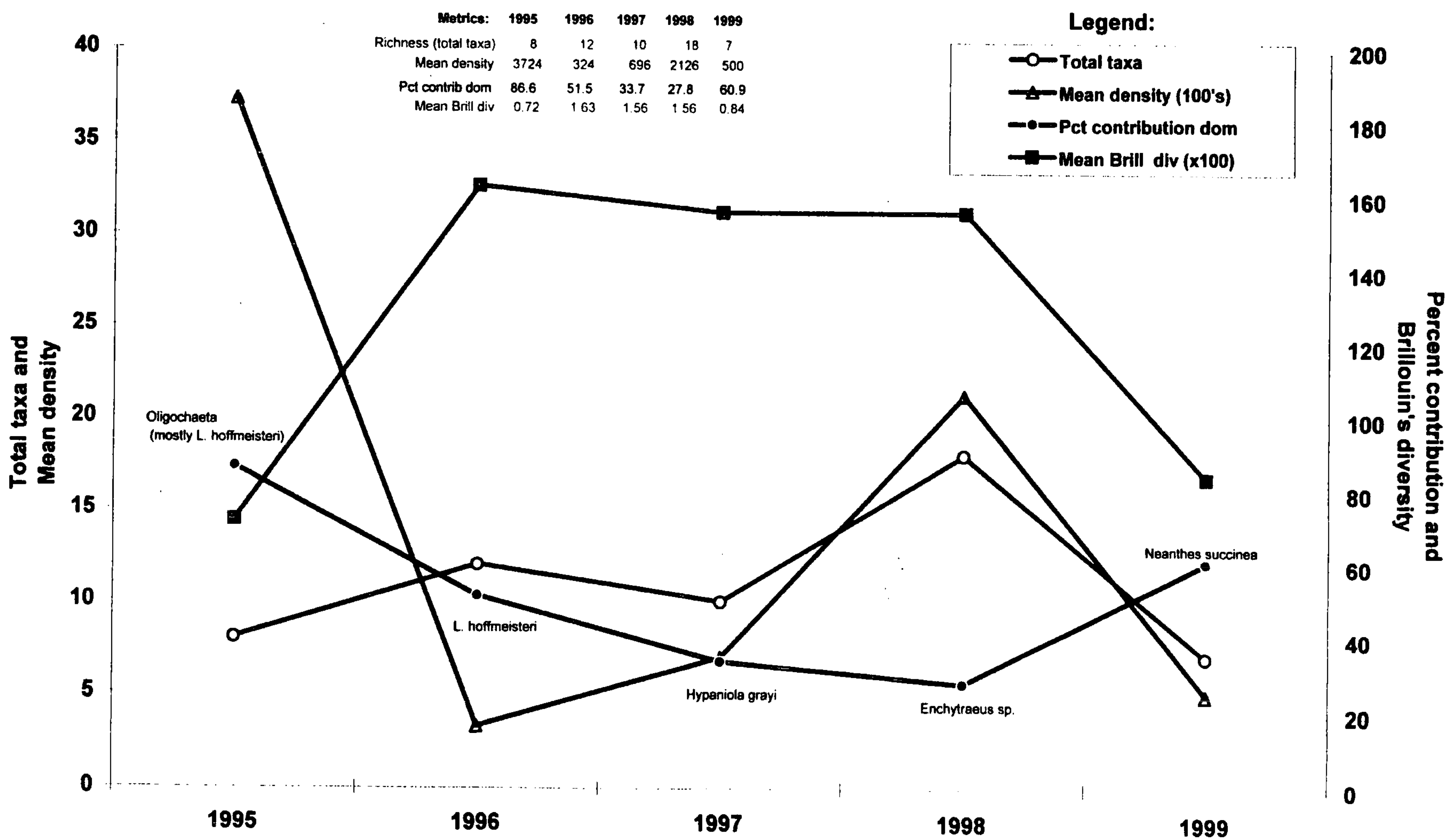


Figure 51. Five year trend in invertebrate community metrics derived from Remediated Zone 3 near Kin-Buc Landfill.

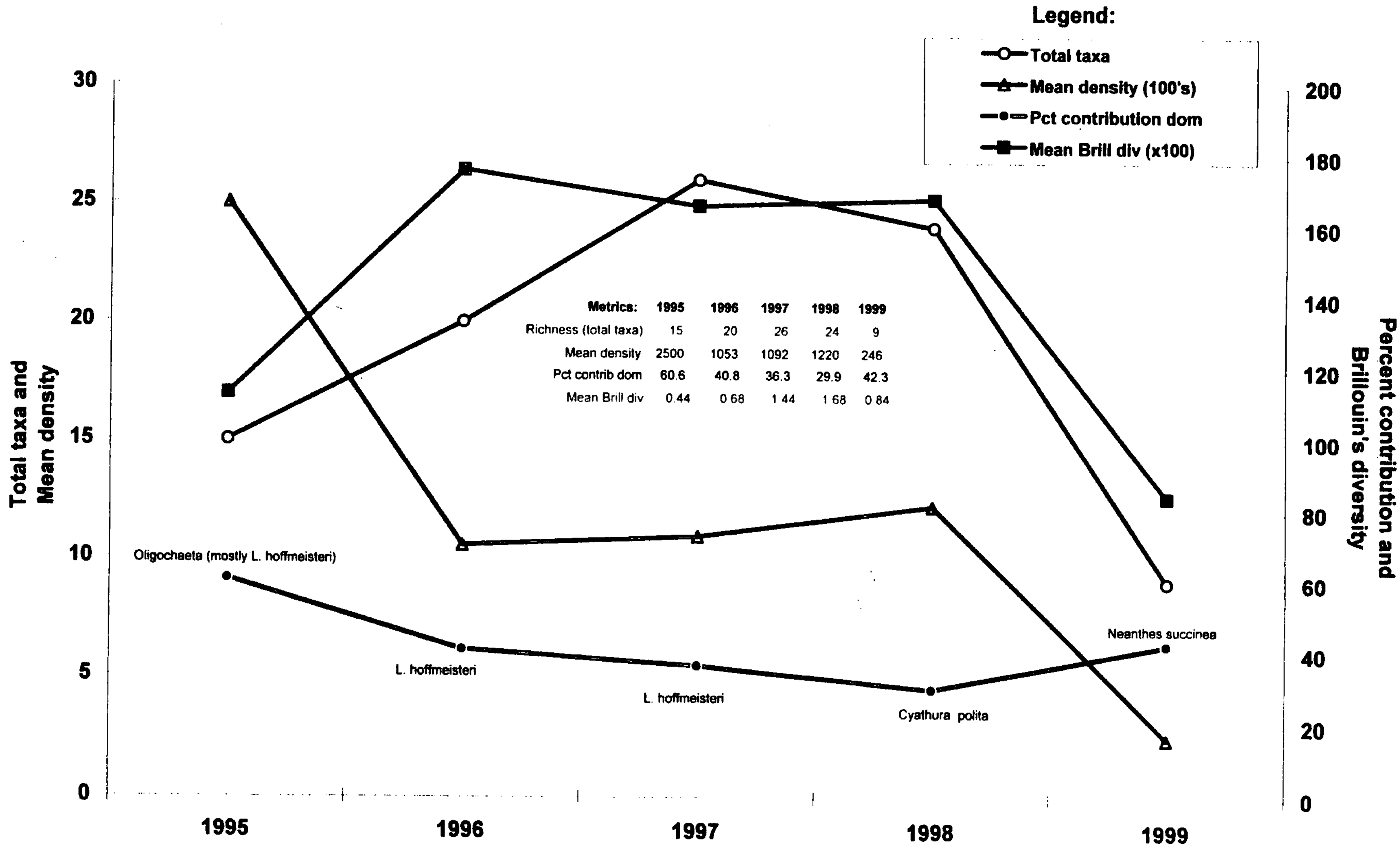
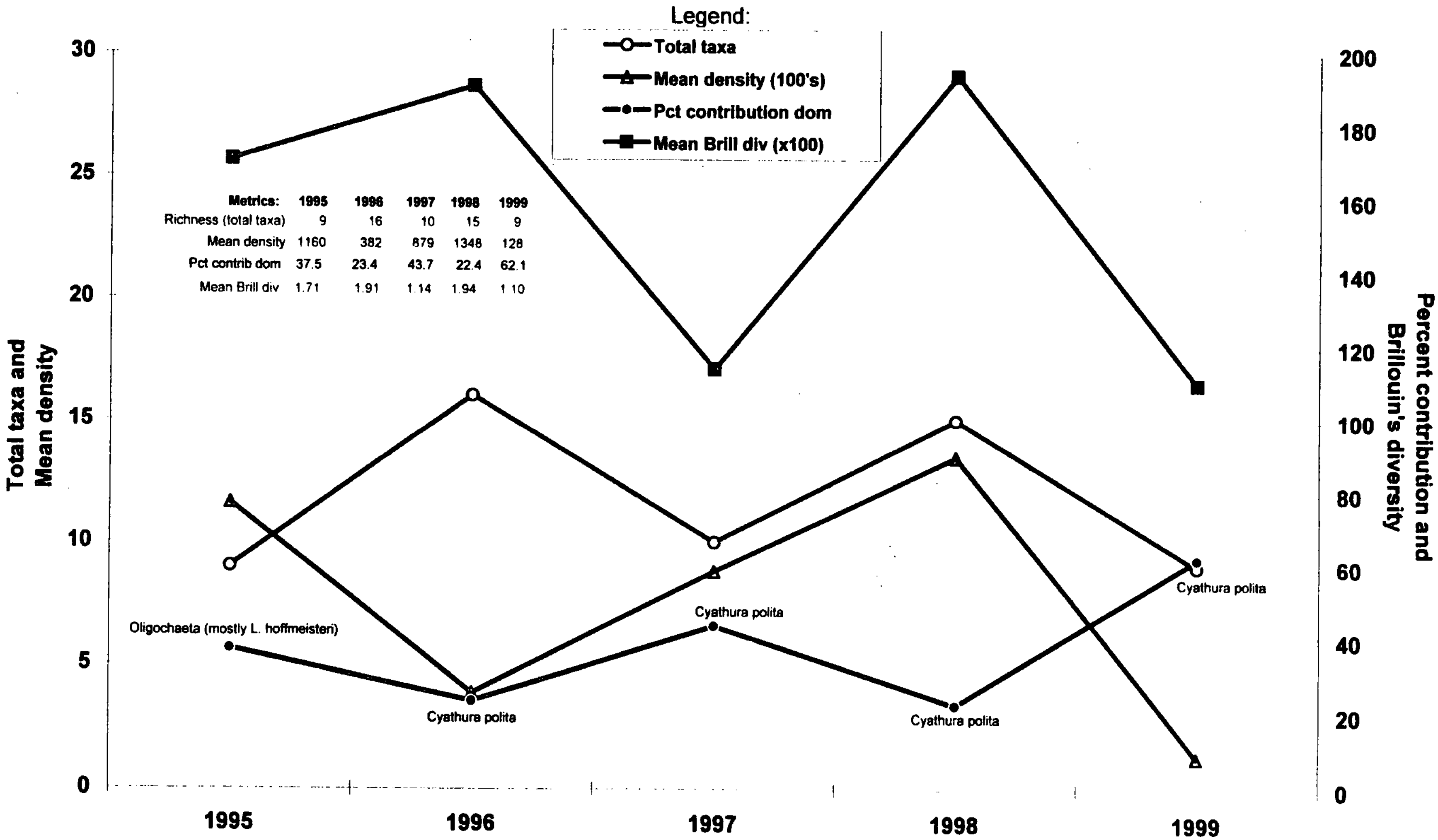
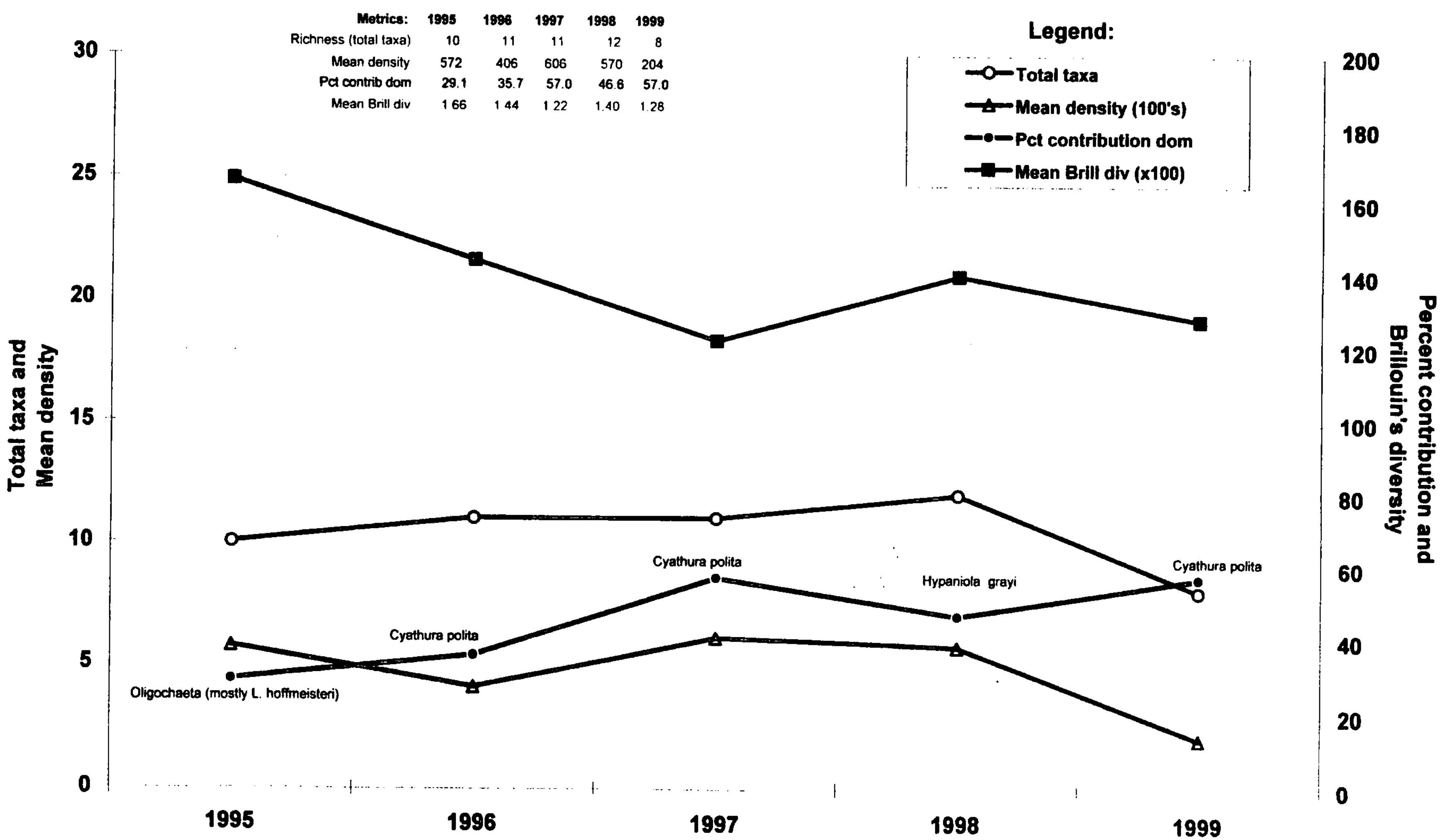


Figure 52. Five year trend in invertebrate community metrics derived from Remediated Zone 4 near Kin-Buc Landfill.



Metrics:	1995	1996	1997	1998	1999
Richness (total taxa)	9	16	10	15	9
Mean density	1160	382	879	1348	128
Pct contrib dom	37.5	23.4	43.7	22.4	62.1
Mean Brill div	1.71	1.91	1.14	1.94	1 10

Figure 53. Five year trend in invertebrate community metrics derived from Remediated Zone 5 near Kin-Buc Landfill.



Metrics:	1995	1996	1997	1998	1999
Richness (total taxa)	10	11	11	12	8
Mean density	572	406	606	570	204
Pct contrib dom	29.1	35.7	57.0	46.6	57.0
Mean Brill div	1 66	1 44	1 22	1.40	1.28

Figure 54. Five year trend in invertebrate community metrics derived from Unremediated Zone 1 near Kin-Buc Landfill.

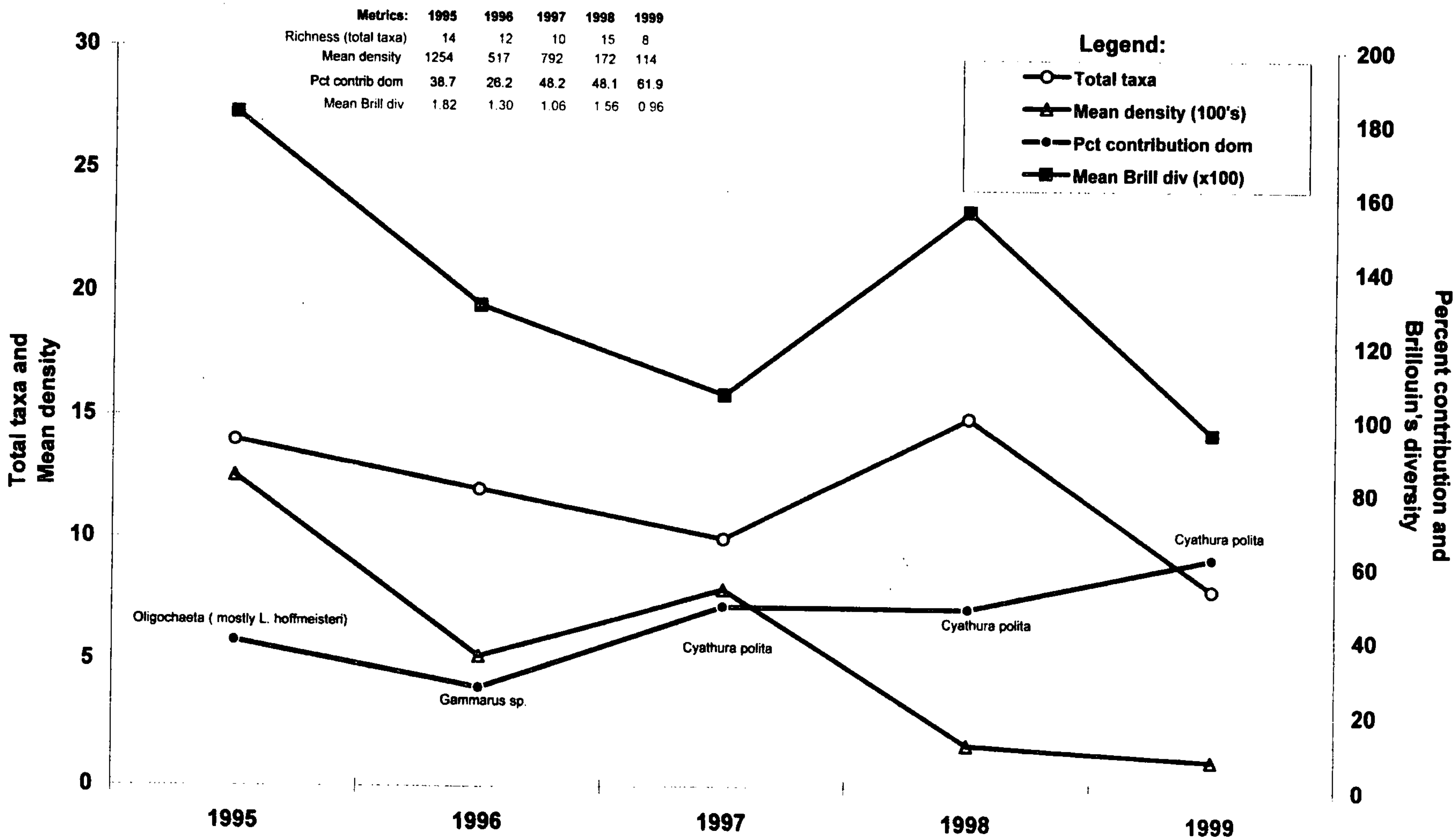
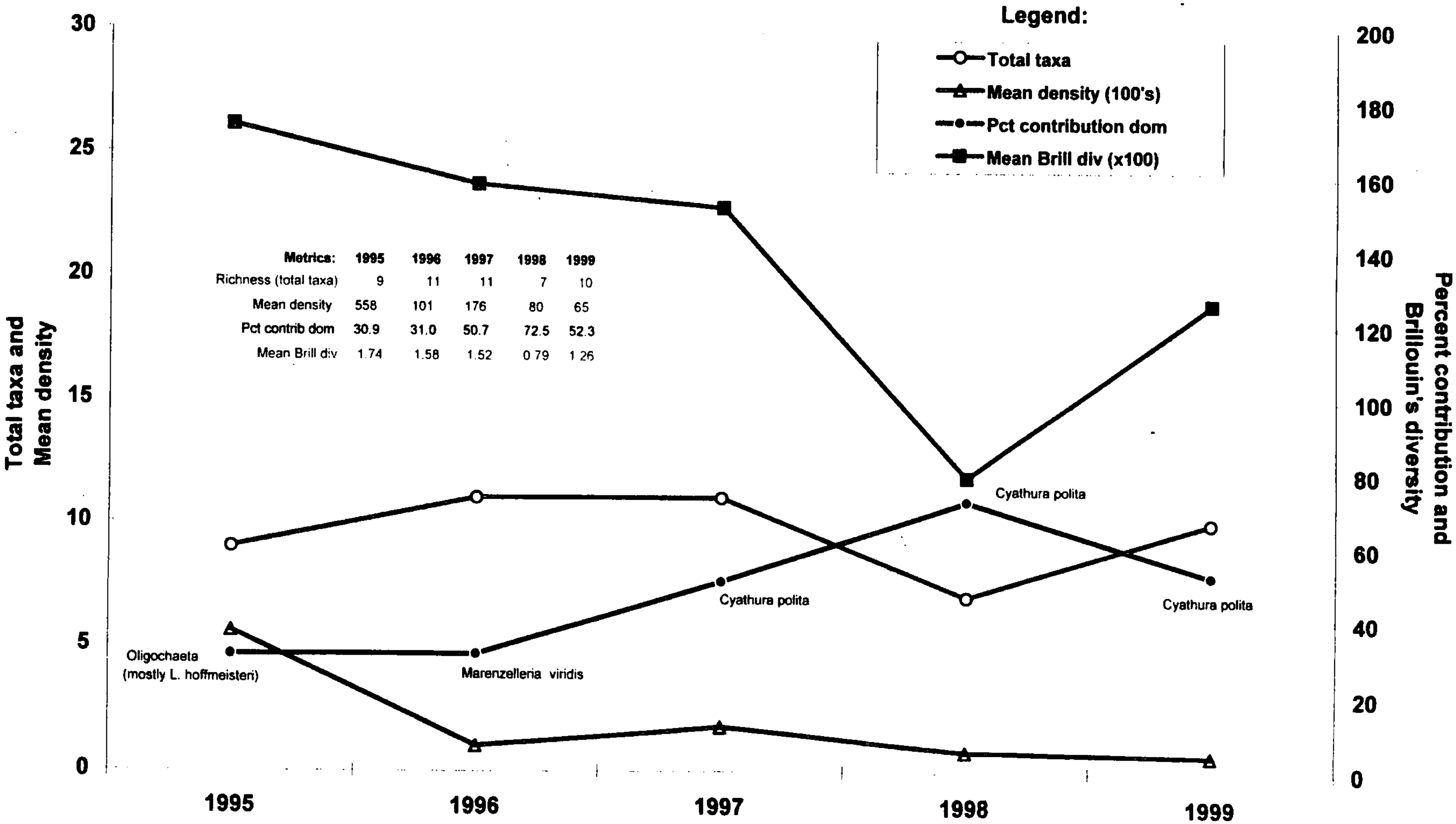
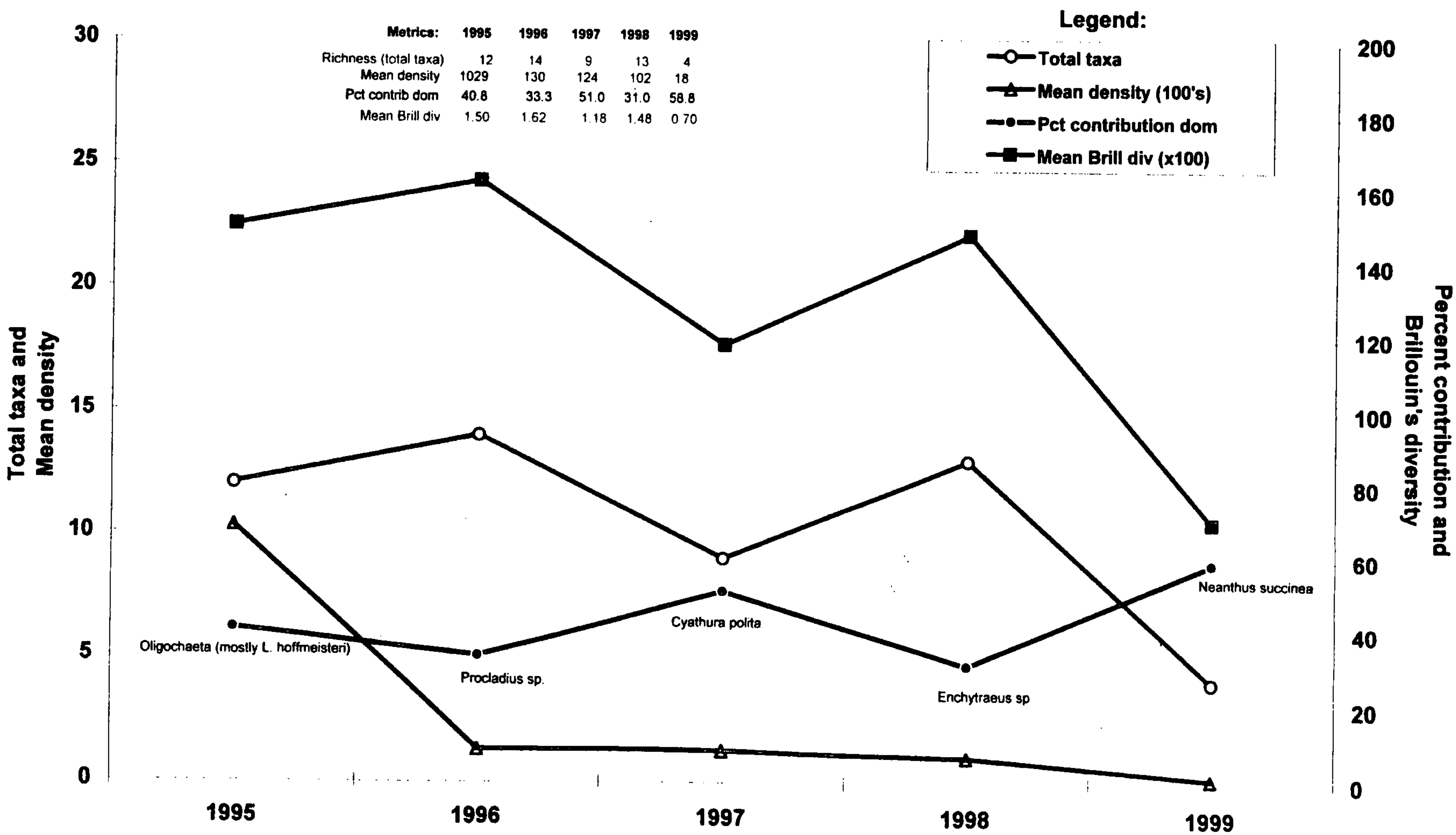


Figure 55. Five year trend in invertebrate community metrics derived from Reference Zone 1 near Kin-Buc Landfill.



Metrics:	1995	1996	1997	1998	1999
Richness (total taxa)	9	11	11	7	10
Mean density	558	101	176	80	65
Pct contrib dom	30.9	31.0	50.7	72.5	52.3
Mean Brill div	1.74	1.58	1.52	0 79	1 26

Figure 56. Five year trend in invertebrate community metrics derived from Reference Zone 2 near Kin-Buc Landfill.



8.0 RECOMMENDATIONS FOR FUTURE STUDY

It seems clear from the data presented above that a substantial reduction in the potential for exposure to humans and wildlife has been achieved as a result of the remedial excavation. Sediment concentrations have remained below the remediation standard throughout most of the study area, sediment concentrations that exceed the remediation standard appear to be localized, and tissue burdens of the fiddler crabs and macoma clams have trended slightly downward. In addition, the fish and invertebrate communities have re-colonized the excavated areas. However, because sediment concentrations exceed 5 ppm at some locations and the mummichog analysis do not show a clear trend, additional monitoring, reduced in scope seems warranted. The following recommendations for future study are offered to maintain a monitoring effort sensitive enough to detect trends in the data set of the most concern, yet remove or reduce components of this effort that are redundant or no longer necessary.

1) All sampling in Reference Creek can be discontinued. The five years of data now available should be sufficient to document the reference condition. The results for the sediment and tissue samples from each target organism have been consistent over time and are unlikely to change.

2) The data from the macoma clam bioaccumulation analysis are generally consistent with the data from the fiddler crab analysis and therefore redundant. It does not appear that two benthic target species are necessary for future study. Because the macoma clam data provides a narrower range of values from which to identify trends, it seems that fiddler crabs are the better target organism. It is recommended that the bioaccumulation analysis be discontinued in lieu of the fiddler crab analysis.

3) The ecological data from both the benthic macroinvertebrate and fisheries collections show that these communities have re-colonized the excavated areas. Because this goal has been successfully met, it is recommended that both sampling efforts be discontinued.

4) The sediment data from Remediated Zones 1, 2, and 5 have been consistently below the remediation standard and appear to be stable or trending downward. Because the remediation goal has been met in these areas it is recommended that the sediment and fiddler crab sampling be discontinued there and future effort focused on the remaining zones where sediment concentrations are higher. Continued monitoring at the remaining four zones would produce sixteen sediment and twelve fiddler crab samples per year from which to analyze trends.

5) The mummichog tissue data do not detect differences between zones due to the mobility of the target species. It does not appear that as many samples will be necessary to discern future trends in the Edmonds Creek data. It is recommended that mummichog sampling be discontinued from Remediated Zones 1 and 2, and Unremediated Zone 3 and future monitoring be based upon a total of ten samples from the remaining five zones.

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APPENDIX A

QUALITY CONTROL: SEDIMENT

Quality Control conducted for the sediment samples included analysis of field blanks, field duplicates, laboratory control samples, surrogate recoveries using tetrachlorometaxylene (TCX) and decachlorobiphenyl (DCB), and matrix spike/matrix spike duplicates (MS/MSD). Quality Control results for PCB analyses are shown below. Additional Quality Control data for TOC, percent moisture, and grain size analyses are on file at Normandeau and available upon request. A field blank was prepared on 4 August. Results for all Aroclors were non-detectable.

Field duplicates were submitted from two sample locations. Percent differences, calculated from the average of the two values, are as follows:

Sample	Date	Result (ppm)	Percent Difference
A42+25/46+50	3 Aug	13.850	
A42+25/46+50 Dup	3 Aug	8.962	43
RA-ABIO-01/01A	3 Aug	0.834	
RA-ABIO-01/01A Dup	3 Aug	0.691	19

Where duplicate results were obtained, means were calculated on Table 1 using the average of the two values.

Two laboratory control samples were analyzed using a sodium sulfate matrix. The field blank obtained from a distilled water matrix was also analyzed. Results for the laboratory control samples are reported as follows:

Aroclor	Percent Recovery	Duplicate	Percent Difference	Limits (Percent)
1016 ($NaSO_4$)	94	-	-	62 - 126
1260	91	-	-	67 - 120
1016 ($NaSO_4$)	90	-	-	62 - 126
1260	87	-	-	67 - 120
1016 (water)	79	80	2	52 - 111
1260	84	83	1	60 - 119

All laboratory control results were within acceptable limits.

Surrogate recoveries were analyzed with each sample. Quality Control is considered acceptable if results for one of two compounds fall within limits. Results are shown below:

Edmonds Creek Zones	TCX Percent Recovery	Limits (Percent)	DCB Percent Recovery	Limits (Percent)
Remediated Zone 1:				
A10+50R	79	24-136	71	1 - 190
A10+50L	81	24-136	90	1 - 190
A10+50/12+00	86	24-136	33	1 - 190
A12+50L	84	24-136	75	1 - 190
Remediated Zone 2:				
A21+00L	90	24-136	78	1 - 190
A21+00/22+00	99	24-136	57	1 - 190
A22+00R	86	24-136	35	1 - 190
A22+50L	83	24-136	70	1 - 190
Unremediated Zone 2:				
UN-ABEN-02R	85	24-136	94	1 - 190
UN-ABEN-02AL	158	24-136	208	1 - 190
UN-ABIO-02R	89	24-136	100	1 - 190
UN-ABIO-02/02A	103	24-136	130	1 - 190
Remediated Zone 3:				
A31+25L	89	24-136	116	1 - 190
A31+25/32+25	124	24-136	145	1 - 190
A33+00R	74	24-136	86	1 - 190
A33+00L	110	24-136	129	1 - 190
Remediated Zone 4:				
A42+25R	89	24-136	111	1 - 190
A42+25/46+50	85	24-136	104	1 - 190
A42+25/46+50 Dup	85	24-136	112	1 - 190
A46+75R	74	24-136	78	1 - 190
A46+75L	83	24-136	96	1 - 190
Remediated Zone 5:				
A50+50L	76	24-136	85	1 - 190
A51+00R	82	24-136	98	1 - 190
A51+00/52+00	86	24-136	104	1 - 190
A52+50R	81	24-136	84	1 – 190

Edmonds Creek Zones	TCX Percent Recovery	Limits (Percent)	DCB Percent Recovery	Limits (Percent)
Unremediated Zone 1:				
UN-ABEN-01L	88	24-136	107	1 - 190
UN-ABEN-01AR	93	24-136	114	1 - 190
UN-ABIO-01AL	122	24-136	154	1 - 190
UN-ABIO-01/01A	61	24-136	75	1 - 190
Reference Creek Zones				
Reference Zone 1:				
RA-ABEN-01L	88	24-136	63	1 - 190
RA-ABEN-01AR	86	24-136	75	1 - 190
RA-ABEN-01AL	82	24-136	76	1 - 190
RA-ABEN-01/01A	83	24-136	76	1 - 190
RA-ABEN-01/01A Dup	87	24-136	78	1 - 190
Reference Zone 2:				
RA-ABEN-02L	84	24-136	77	1 - 190
RA-ABEN-02AR	88	24-136	62	1 - 190
RA-ABEN-02AL	84	24-136	74	1 - 190
RA-ABEN-02/02A	81	24-136	75	1 - 190
Field Blank	0	33-120	0	7 - 120

All results were within acceptable limits except for those for the sample collected at Station UN-ABEN-02AL and the field blank. Surrogate recoveries for sample UN-ABEN-02AL were outside QC limits due to a matrix problem evident in the sample chromatogram (see notation on Analysis Report, page 2 of 5, in Appendix A). The field blank was re-extracted and a second set of surrogate recovery results were within limits (see notation on Analysis Report, page 2 of 5 in Appendix A).

Matrix spike and matrix spike duplicates are reported for two samples. Samples were spiked with Aroclors 1016 and 1260. These results were:

Matrix	Aroclor	Percent Recovery MS	Percent Recovery MSD	Percent Difference	Limits (Percent)
Sediment	1016	92	99	8	62 - 126
	1260	76	85	9	67 - 120
Sediment	1016	204	125	48	62 - 126
	1260	75	35	42	67 - 120

Sample results are considered acceptable if one of two Aroclors fall within limits. Acceptable results were obtained for both samples.